MECHANICAL DRAWING

OUTLINE OF COURSE ENGINEERING 3a, HARVARD UNIVERSITY

REVISED FOR 1906-07

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Special acknowledgment is due Professor G. C. ANTHONY, whose Text Book, "Mechanical Drawing," has suggested several of the exercises and problems given in these notes.

MEMORANDUM

General Directions

1. Directions in regard to the conduct of the course will be given at the lectures, and, when necessary, will be published in the Bulletin Board. Each student will be expected to note these directions, or, if absent from a lecture, to obtain them from some fellow-student. In any case he will be held responsible for all information given at the lectures or in the Bulletin Board.

Special Directions in Writing

2. Special directions given by any of the instructors in regard to the work of the course will be held valid only when accompanied by a written statement on the sheets, or on suitable blanks. Oral instructions cannot be verified, and will, therefore, be given no consideration.

Attendance

3. Credit for attending a meeting of the course is given on the understanding that a student has reported *at the office* at the beginning of the session, and has been in continuous attendance from that time until the end of the session.

Excused Absences

4. A student whose absences have been excused at the office can have his attendance record in this course corrected by bringing a memorandum suitably endorsed by the office. This memorandum should be presented *not later than one week* after the absence.

Handing in Work

5. All work, to be accepted, must be handed in at the appointed times by the student personally, and not by proxy.

Overdue Work

6. A date set for overdue work will be considered final. No work presented after that date will be accepted, unless previous agreement in writing has been made.

Instruments and Materials

7. Each student is strongly advised to place an identifying mark on all his materials, including drawing instruments. All instruments and materials are left in the lockers during the year at the student's own risk, and must be removed from the lockers *on or before the date set for the final examination.* All articles not removed will be considered abandoned, and will be treated accordingly.

Tests

8. Tests will be held from time to time during the year. The results of these tests will have a very considerable weight in judging the work of the course. No make-ups will be given, but in special cases where a student is unable to be present at the time of a test, he may make arrangements to take it *in advance.* Unsatisfactory work in the tests *may* serve as a ground for failure in the course, without regard to the quality of the drafting work.

METHOD OF LAYING OUT DRAWING SHEET—USE OF MATERIALS

LECTURE DATE.............................

PLATE 1—GENERAL INSTRUCTIONS

METHOD OF LAYING OUT DRAWING SHEET—USE OF MATERIALS

DIRECTIONS

I. Fold and cut sheet into four equal parts.

The kind of paper used in this course is known as "**Duplex.**"

II. Thumb tack one part to Drawing Board. (One thumb tack in each corner.)

III. *Fig. 10.* With T-square laid across corners draw *short*, *light* lines **A B** and **C D**, thus finding approximate centre of sheet. (**Use 6 H Pencil.**)

IV. *Fig. 11.* With T-square draw **E F** (*light*) through centre. With *Triangle* draw **G H.** These are called "**Centre Lines**" of sheet.

V. *Fig. 12.* Along *Centre Lines* lay off **9** inches horizontally and **6** inches vertically, each side of centre. (Use *Triangular Scale* as shown.) With *T*-square and *Triangle* draw rectangle as shown. This is called the "**Cutting Line.**"

VI. *Fig. 13.* Again, lay off **8** *in.* and **5** *in.* on Centre Lines and complete second rectangle. This is called the "**Border Line.**"

VII. *Fig. 14.* The result is a sheet as shown; **18** *in.* by **12** *in.* (*outside measurement*) with **1** *inch* Border all round. This is called the "**Layout of Sheet.**"

NOTES

A. **Pencil.***

(*a*) **6 H** pencil sharpened, on *Sand Paper* pad, with *chisel* point. (*Fig. 1.*)

Used for *Laying out Sheets* and *Blocking out Drawings.*

(*b*) **2 H** pencil sharpened, on pad, with *round* point. (*Fig. 2.*)

Used for *Pointing Off Distances*, *Strengthening Outlines*, and *Lettering.*

(*c*) **Compass** pencil sharpened as in— (*Fig. 3.*)

Use **6 H** for Blocking out; **2 H** for Strengthening.

Use small *Needle Point* end in other leg of compasses. (*Fig. 4.*)

B. **Pen.**

(*a*) Have *both nibs* touching paper (*Fig. 5*), not (*Fig. 6*).

(*b*) *Do not fill pen too full.*

(*c*) *Clean* pen often with pen-wiper.

C. **T-Square.**

(*a*) Always use *T-Square* at *Left* end of board. (*Fig. 7.*)

If left-handed, change to Right end.

(*b*) Always draw along *upper* edge of *T*-square.

D. **Triangles.**

(*a*) Always use *triangles* on *top edge* of *T*-square.

Wherever possible draw with light coming from Direction (**A**). (*Fig. 7.*)

(*b*) To draw *Parallel* lines, slide triangle along some Straight Edge (either *T*-square or another triangle). (*Fig. 8.*)

(*c*) To draw *Perpendicular* to a given line, as **A B**, place triangle against a Straight Edge, as shown in *full lines;* then turn triangle to *dotted* position, slide along to required point and draw perpendicular **C D.** (*Fig. 9.*)

* Whenever possible draw the lines from **Left** to **Right** and from **Bottom** towards **Top** of sheet.

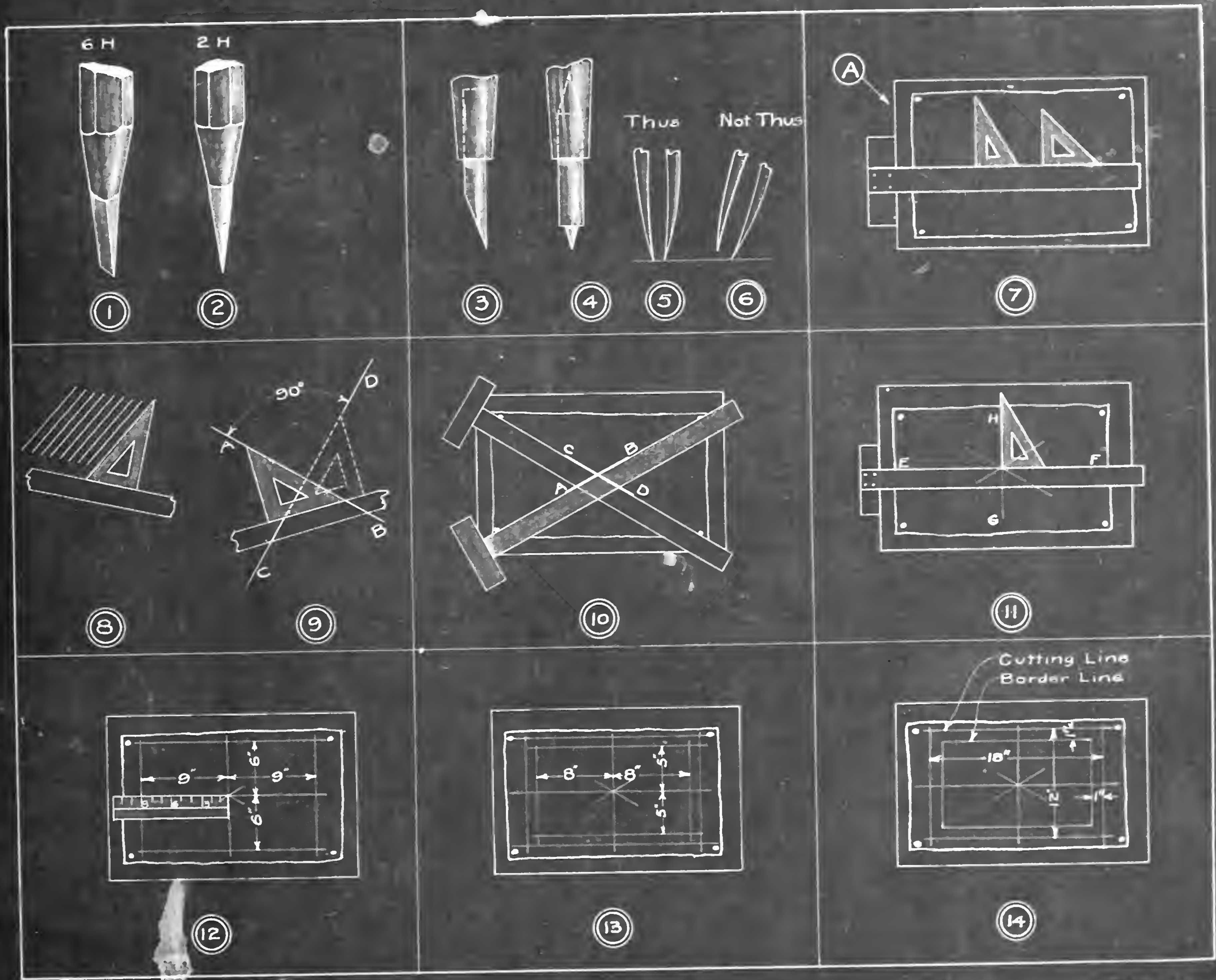

6 H
2 H
1
2
3
4
Thus
Not Thus
5
6
A
7
90°
D
A
B
C
8
9
C
B
A
D
10
H
E
F
G
11
9"
9"
6"
6"
12
8"
8"
5"
5"
13
Cutting Line
Border Line
18"
14

Plate 1

LECTURE DATE________________

DIRECTIONS

I. Lay out sheet as explained. (PAGE 6.)

II. Draw all *guide lines* for letters, *very light*, spaced as shown. Use **6 H** pencil, sharpened as shown by PAGE 6–A–a.

III. Draw *freehand* the letters and figures indicated on opposite page.

This page shows arrangement only. Consult PAGE 105 for construction of letters.

(*a*) Use **2 H** pencil. (Sharpened as shown by Page 6–A–b.)

(*b*) Press lightly.

(*c*) Make letters *round* and *full*.

(*d*) Avoid crowding.

IV. Make the small letters $\frac{1}{8}$ *inch* high; the *capitals* and *figures* $\frac{3}{16}$ *inch* high.

This size will be called "**Standard,**" and will be used for general lettering throughout the course.

In *fractions* make numerator and denominator figures each about $\frac{2}{3}$ standard size.

V. Add Title.

(*a*) Draw base line for title $\frac{1}{2}$ *inch* below *Border Line.*

(*b*) Begin title far enough to the left to end exactly under (**A**).

To do this, determine length of title by blocking it out on another paper, or on margin outside of Cutting Line.

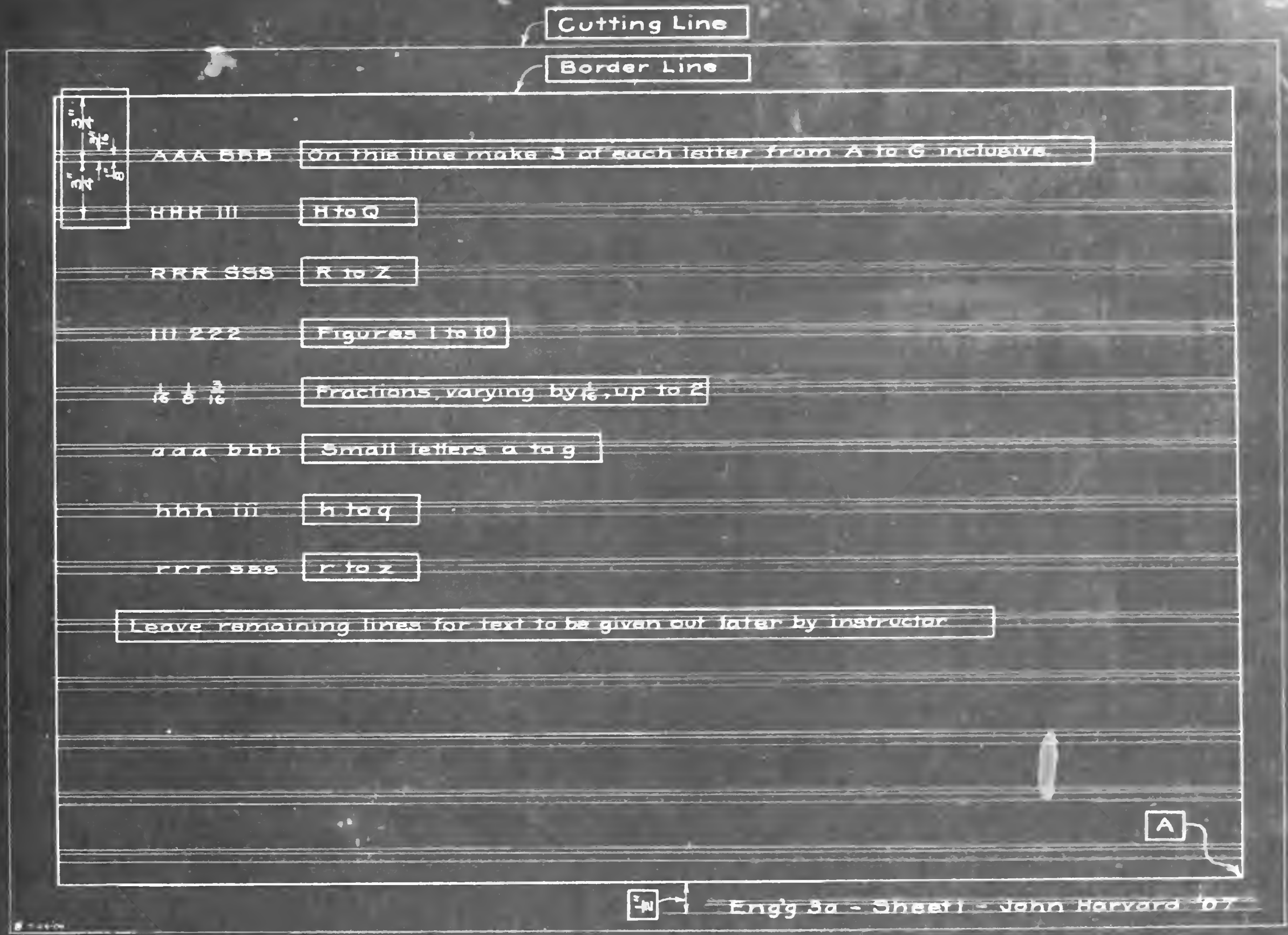
NOTES

A. All statements enclosed in *Rectangles* are to be omitted from the drawing sheets.

They are for direction only.

B. The numerical dimensions given on the blue prints may not always agree with the "scale" (proportion) or with the exact arrangement shown. In such cases follow the *dimensions*. This is the general rule in reading working drawings.

C. The lettering used in this course is an adaptation of the "*Reinhardt*" **Gothic Alphabet.** See "*Lettering*" by Charles W. Reinhardt.



For Construction of Letters see page 105

Plate 2

LECTURE DATE ....

DIRECTIONS

I. *Upper Left.* HORIZONTAL LINES.

(*a*) Space off with scale along *Vertical Centre Line* of sheet.

(*b*) Begin at *Top* and work down. (Use *T*-square.)

II. *Upper Right.* VERTICAL LINES.

(*a*) Space off along *Horizontal Centre Line*.

(*b*) Begin at *Left* and work to *Right*. (Use *T*-square and *Triangle*.

III. *Lower Left.* SLANTING LINES.

(*a*) Use *T*-square and *45° Triangle*.

IV. *Lower Right.* PARALLEL LINES.

(*a*) Draw Parallelogram **A B C D.**

(*b*) *Outside* draw lines parallel to **A B.**

(*c*) *Inside* " " " " **B C.**

(Use Method given on PAGE *6–D–b*.)

V. Add *Title* as shown on PLATE 2.

NOTES

A. Lines to be : —

(*a*) **Fine.**

(*b*) **Uniform.**

(*c*) **Accurately drawn.**

(Use **6 H** pencil, sharpened as shown by PAGE *6–A–a*.)

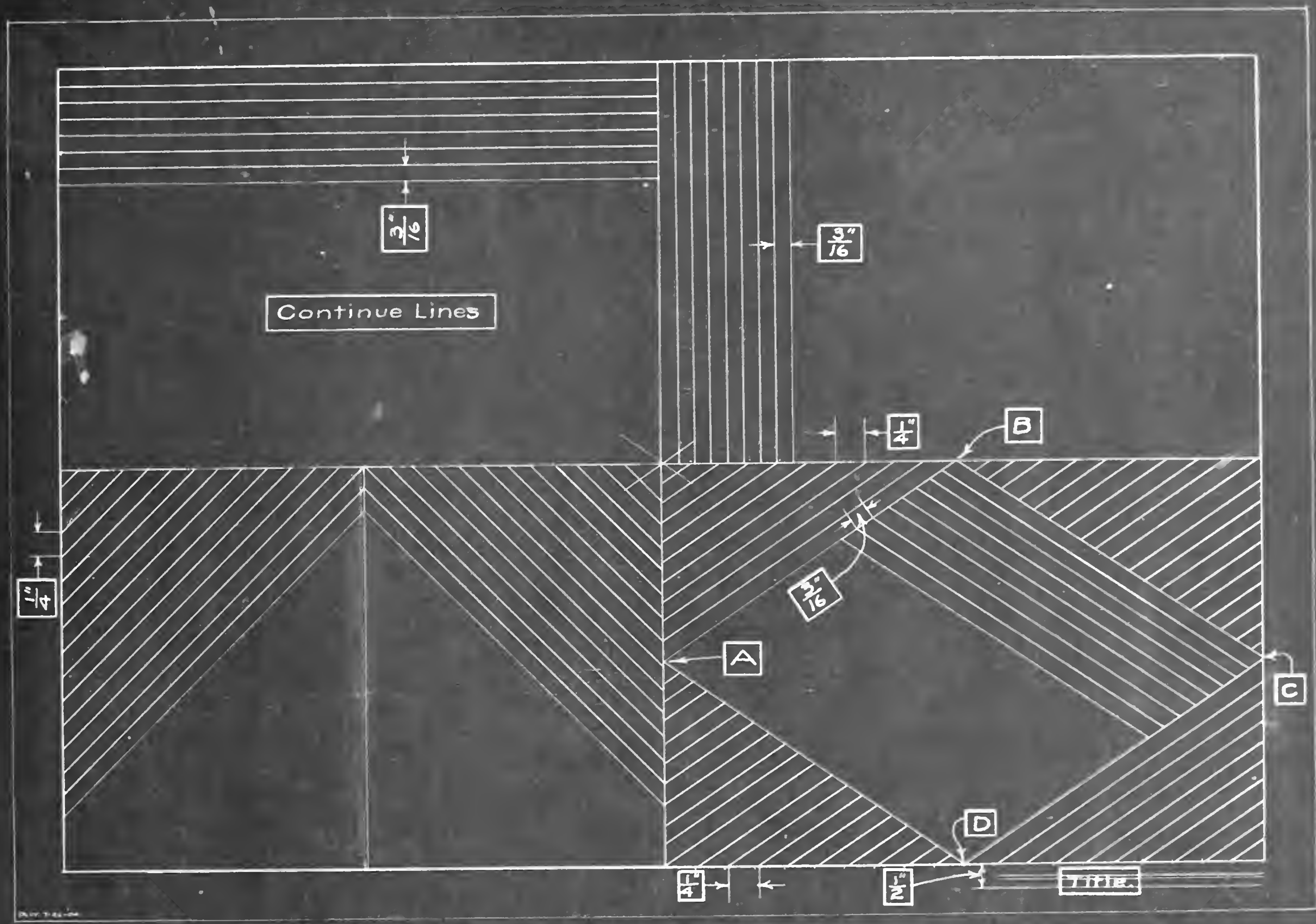


Plate 3

LECTURE DATE..

DIRECTIONS

I. *Ex. 1.* Given two Circles, *3 inches* diam. and *4 inches* diam., respectively.

Circumscribe Hexagons.

The larger with two sides horizontal, the smaller with two sides vertical.

Use *T*-square and *60°* Triangle *only*.

II. *Ex. 2.* Given Circle $3\frac{1}{2}$ *in.* diam.

(*a*) Draw lines *15°* apart as shown. Use *T*-square, **45°** and **60°** Triangles *only*.

(*b*) On left half of Circle draw *Tangent* at end of *every other line* by method of 2 Triangles. See PAGE *6–D–c*.

(*c*) On right half of Circle draw *Tangent* at end of *any 3* lines by geometry.

See note at bottom of opposite page.

III. *Ex. 3.* Given Circle $3\frac{1}{2}$ *in.* diam. Lay off angles as shown. (Use *Protractor.*)

Do not add arrows or figures.

III. *Ex. 4.* Given Line at angle of $37\frac{1}{2}°$ with Horizontal. (Use *Protractor.*)

On this line as base draw a regular *Hexagon*, each side $= 1\frac{1}{2}$ *inch*. (Use any accurate method that suggests itself.)

V. *Ex. 5.* Given Circle $3\frac{1}{4}$ *in.* diam. Inscribe a regular *Pentagon.* (For other polygons, see PAGE 107.)

VI. *Ex. 6.* Given Circle *4 in.* diam. Inscribe small circles as shown.

Use *Bow Pencil* on smaller circles.

NOTES

A. *Straight Lines* and *Circles* to be: —

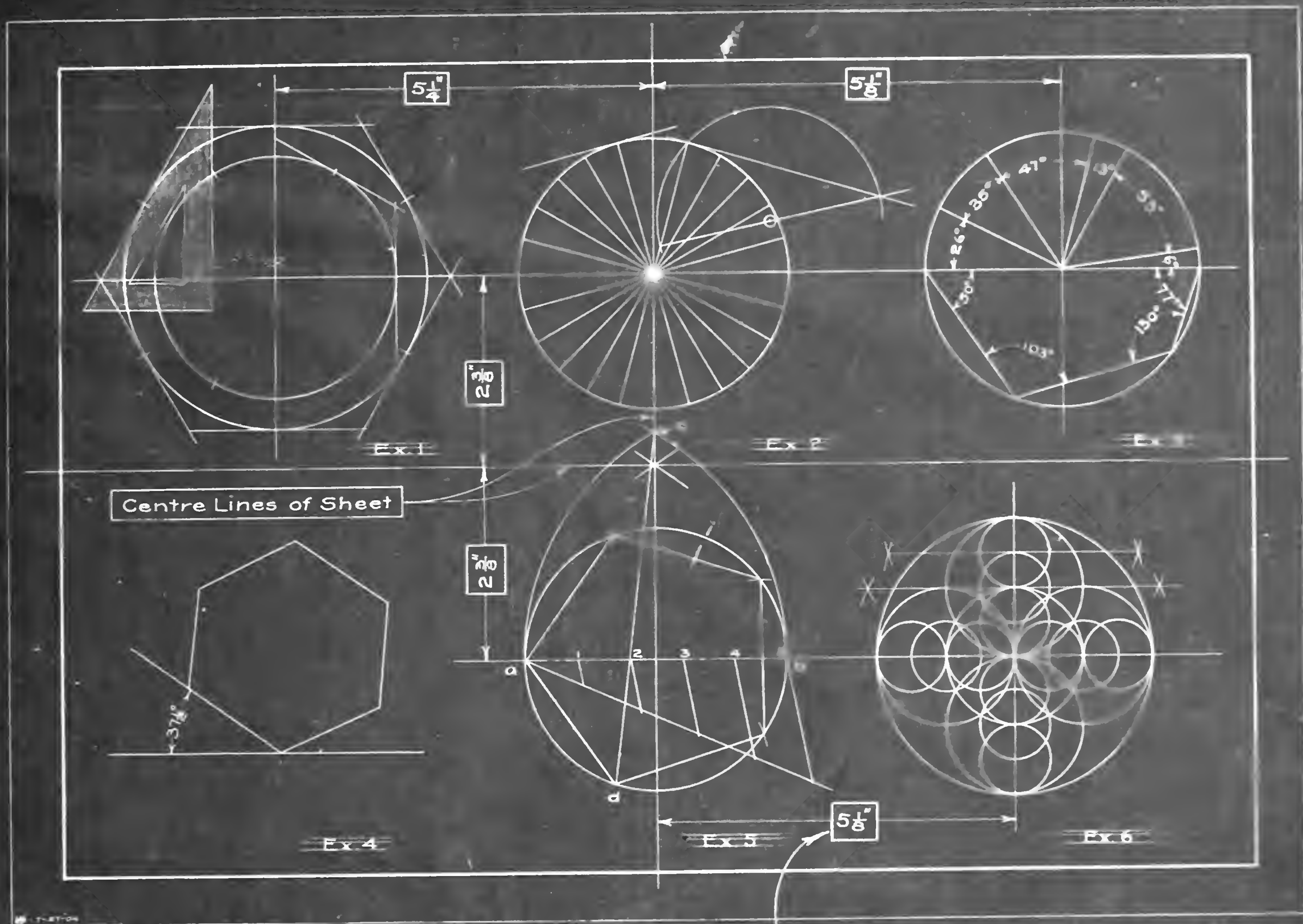
(*a*) *Fine.*

(*b*) *Uniform.*

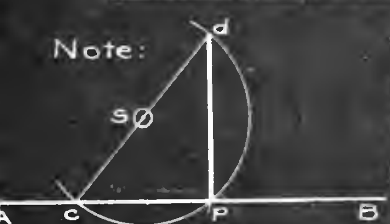
(*c*) *Accurately drawn.*

Use *6 H* Pencil and *6 H* lead in Compasses.

(Sharpened as shown by PAGE *6–A–c*.)



Note:



To erect a perpendicular to AB at p.
Draw circle thro' p, center s = any point.
Draw cd thro' s. pd = perpendicular.
(Angle cpd inscribed in semi-circle = 90°)

Follow dimensions rather than scale
See note B on page 10

Plate 4

LECTURE DATE ....

DIRECTIONS

I. Two sheets will be made from this plate.

On the first draw the upper row of figures (Ex. 1, 2, 3, and 4), then repeat them below in place of Ex. 5, 6, and 7.

On the second draw Ex. 5, 6, and 7 in the upper half of the sheet and repeat them below.

II. Both sheets are to be finished *in pencil only* and handed in. At a later date they will be given back for an exercise in inking.

SPECIAL DIRECTIONS FOR INKING

1. (*a*) Do not fill pen too full. (See PAGE *6–B.*)

   (*b*) Clean pen often.

2. All lines to be **Black** and of **Medium Width,** *except* **Border,** which is to be **Heavy** and added *last.* (See note on blue print.)

3. In inking, proceed in same manner as with pencil.

   Begin at *Left* and work towards *Right*, and from *Top* work towards *Bottom*.

4. In *Ex. 4* draw lines *to* point **P,** *not away* from it.

5. In *Ex. 5 and 7*, omit Centre Lines.

6. In *Ex. 6*, ink only the final outline as shown at bottom of the blue print.

7. In Lettering use drawing ink and writing pen.

8. *Do not ink Cutting Line.*

NOTES

Lines to be: (*a*) *FINE.*

(*b*) *UNIFORM.*

(*c*) *ACCURATE.*

Ex. 1. Space lines $\frac{1}{4}$ *in.* apart.

Ex. 2. Space points $\frac{1}{4}$ *in.* horizontally and vertically. (Lines at 45°.)

Ex. 3. Space lines $\frac{1}{4}$ *in.* apart.

First draw diagonal; then draw lines in order, **A, B, C, D,** etc.

Ex. 4. Space points $\frac{1}{2}$ *in.* apart.

Ex. 5. **Spiral.**

(*a*) Make **a c** = $\frac{1}{4}$ *in.*; **a b** = $\frac{1}{8}$ *in.*

(*b*) With **a** as centre, draw all semicircles *above* horizontal line. With **b** as centre, all semicircles *below.*

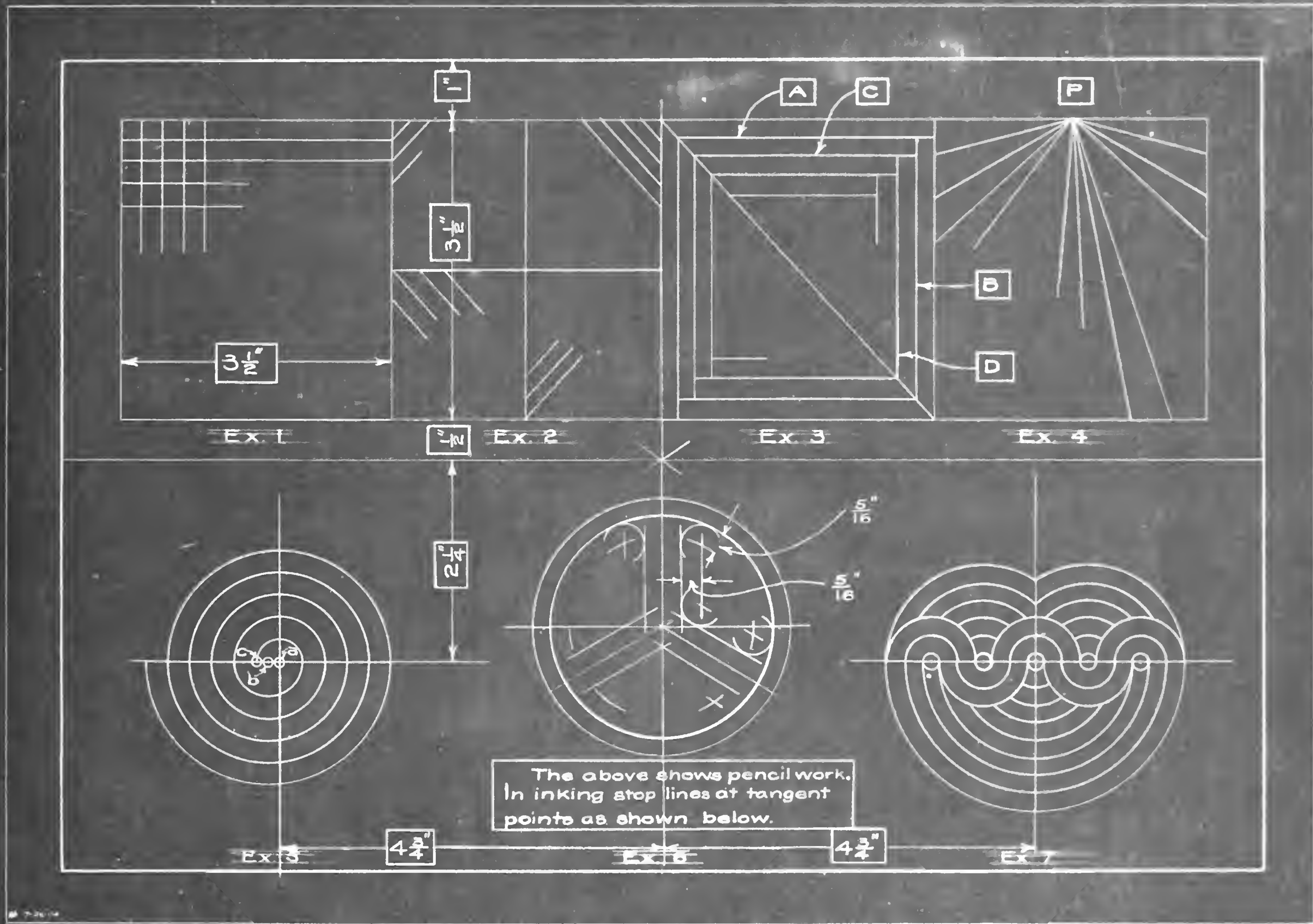
Use **a** and **b** alternately to develop *Spiral.* Continue as far as possible without conflict.

Ex. 6. **Tangent Arcs.**

Outside circle of rim *4 in.* diam.; inside, $3\frac{1}{2}$ *in.* Spokes $\frac{3}{4}$ *in.* wide, centre lines 120° apart. Radius of tangent arcs $\frac{5}{16}$ *in.*

Ex. 7. Space points $\frac{1}{4}$ *in.* apart on horizontal line. Complete figure as shown.

Use *Bow Pencil* for small circles.
Draw all curves of one radius at one time.



NOTE: In Inking make.
Medium Lines about thus:
Border Line about thus:

Ex 6

Plate 5

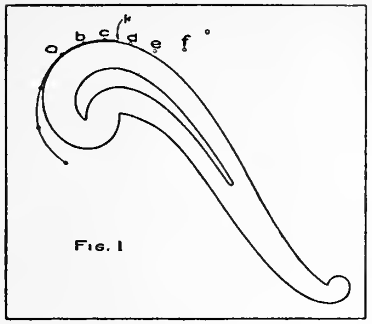


Fig. 1

Use of French Curve or Scroll

Given a series of points to be joined by a *smooth curve.*

Find portion of Scroll to fit as many points as possible (as **a, b, c, d**). Then draw from **a** to **k** (about half way between **c** and **d**). Change Scroll to fit **c d e f**, etc. (as many more points as possible) and continue the curve from **k** to half way between the last two points. Continue thus.

LECTURE DATE..

DIRECTIONS

I. From the problems on this plate a selection will be made. The data and layout will be given out at the lecture.

II. Carry out the construction (very lightly with **6H** pencil) for as many points as seem necessary to draw *accurately* and *smoothly* each curve. Then draw the outlines of the curves using "**French Curve**" or "**Scroll**". (See PAGE 25.)

At ends, if French Curve does not fit the points well, short arcs may be drawn with bow pencil.

III. This sheet may be given back later for an exercise in inking with French Curve.

NOTES

A. **Ellipse — Parabola — Hyperbola.**

These curves belong to the family of **Conic Sections,** so called because they are derived by the intersection of planes with the surface of a **Cone.**

Their exact derivation will be taken up in PLATE 15. This sheet deals merely with certain geometrical methods of drawing them.

B. PROBLEM 1. **Ellipse** (*First method*).

(*a*) The Ellipse can be defined as the path traced by a point, the *sum* of whose distances from two fixed points always remains constant.

The two fixed points ($\mathbf{f}_1$ and $\mathbf{f}_2$) are called "**Foci**" (singular, "**Focus**").

The long diameter or *Length* of Ellipse (**a b**) is called the "**Major Axis.**"

The short diameter or *Width* (**c d**) is called "**Minor Axis.**"

(*b*) After locating the foci, find several points in each quadrant as indicated for point **p**. Join them with the French Curve.

It will be seen that the sum of the distances from the *Foci* to the moving point will always equal the *Major Axis*. Then, with Major and Minor Axes given, the Foci can be found by drawing arc with Radius $\mathbf{R} = \frac{1}{2}$ *Major Axis*, and one end of Minor Axis as centre. The rest of the construction follows the definition given above. (See diagram.)

NOTES (CONTINUED)

C. PROBLEM 2. **Ellipse** (*Second Method*).

This method does not require the foci to be found.

D. PROBLEM 3. **Parabola** (*First Method*).

The Parabola can be defined as the path traced by a point moving so that its distance from a *given point* shall always be equal to its distance from a *given straight line*.

The fixed point (**f**) is called the **focus.**

The straight line (**ab**) is called the **directrix.**

The point (**v**) is called the **vertex.**

After the focus and directrix are located, the construction is carried out as indicated.

E. PROBLEM 4. **Parabola** (*Second Method*).

This method is useful when one desires the parabola to have its vertex at **v** and to pass through another given point (as **a**). Neither the focus nor the directrix is needed.

F. PROBLEM 5. **Hyperbola.**

The Hyperbola can be defined as the path traced by a point moving so that the *difference* of its distances from two fixed points is always constant.

The construction indicated follows the definition.

Compare with first method for the *Ellipse*.

G. PROBLEM 6. **Rectangular Hyperbola.**

The equation of this curve (referred to axes **O X** and **O Y**) is $xy = constant$. The curve is a special case of the *Hyperbola* but further analysis of it is left to Analytic Geometry.

With one point (as **a**) located by the above equation, the curve can be drawn as indicated. If continued it would extend upward from **a.**

This construction is much used in the representation of the *Theoretical Indicator Card* of a *Steam Engine*.

Questions for Consideration

(1) How would the Ellipse change if the *foci* were drawn nearer the centre?

(2) How would the Ellipse change if the *foci* were drawn farther from it?

(3) What would the Ellipse approach in each of the above cases?

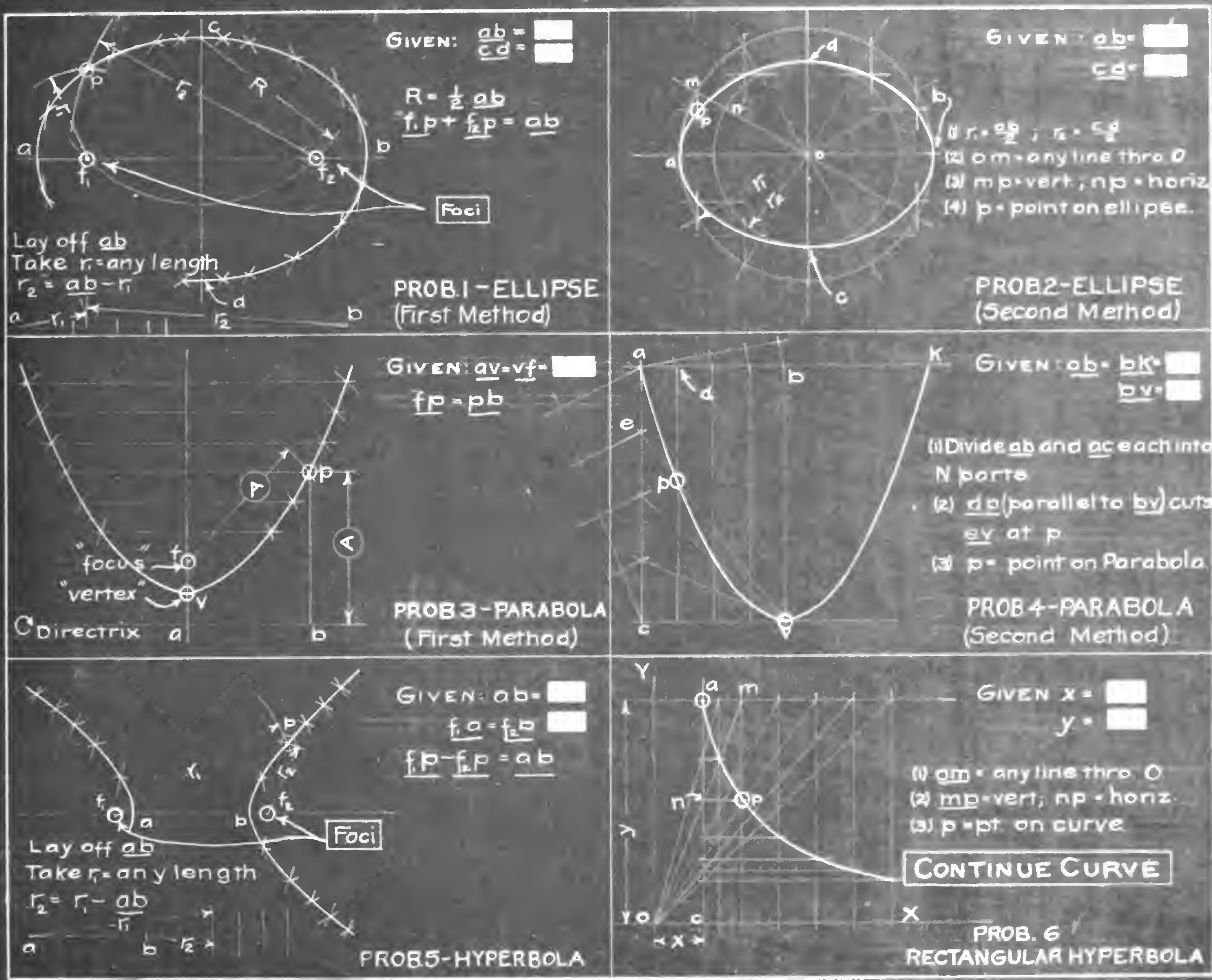

GIVEN: ab = cd =
R = ½ ab
f₁p + f₂p = ab
Foci
Lay off ab
Take r₁ = any length
r₂ = ab − r₁
PROB.1 − ELLIPSE
(First Method)
GIVEN: ab = cd =
(1) r₁ = ab/2 ; r₂ = cd/2
(2) om = any line thro O
(3) mp = vert.; np = horiz.
(4) p = point on ellipse.
PROB.2 − ELLIPSE
(Second Method)
GIVEN: av = vf =
fp = pb
"focus"
"vertex"
Directrix
PROB.3 − PARABOLA
(First Method)
GIVEN: ab = bK = bv =
(1) Divide ab and ac each into N parts
(2) dp (parallel to bv) cuts ev at p.
(3) p = point on Parabola
PROB.4 − PARABOLA
(Second Method)
GIVEN: ab = f₁a = f₂b
f₁p − f₂p = ab
Foci
Lay off ab
Take r₁ = any length
r₂ = r₁ − ab
PROB.5 − HYPERBOLA
GIVEN x = y =
(1) om = any line thro O
(2) mp = vert.; np = horiz.
(3) p = pt. on curve
CONTINUE CURVE
PROB. 6
RECTANGULAR HYPERBOLA

Plate 6

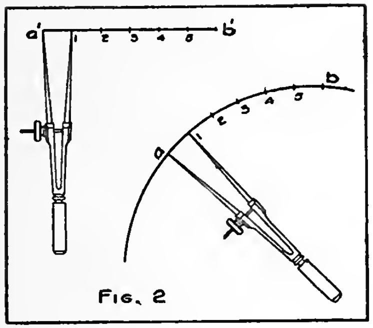


Fig. 2

To Rectify a given Arc

Given arc **a b** (Fig. *2*). Use Bow Spring Dividers. Step off *short distances* along arc **a b** and same number along Straight Line.

This makes **a′b′** equal, approximately, arc **a b.**

Unit distance should be so short that the arc and chord are practically equal.

To Transfer a Gear Tooth Curve

Place *Scroll* to coincide with given curve (**m n**) (Fig. *3*). Mark point **n** on Scroll and draw *Circle* **P** tangent to Scroll at any convenient point (as **t**). Change Scroll to new position and draw **m′n′** as shown.

Alternative Method

Omit *Circle* **P** and use mark (as **s**) to locate curve.

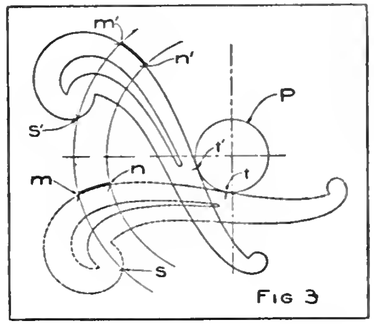


Fig 3

LECTURE

DATE..

DIRECTIONS

I. Begin construction by laying out *Centre Lines* of circles. Draw all construction circles *very light.*

II. Make the size of Rolling Circles as follows: —

Prob. 1. *Rolling Circle* (**R. C.**) = 2″ diam.
Prob. 2. **R. C.** for *Epicycloid* = $1\frac{3}{4}$″ diam.
" " *Hypocycloid* = $2\frac{1}{4}$″ diam.

III. This sheet may be given back later to be used as an exercise in inking.

Questions for Consideration

(1) When the curve of Problem 1 comes back to the straight line, how far will it be from the initial point **O**? (Answer by showing proper dimension line and figures.)

(2) If the diameter of the Rolling Circle for the *hypocycloid* were increased, how would the resulting curve change?

(3) If the diameter becomes = radius of Pitch Circle, what kind of a curve would result?

* Cycloid — κύκλος = "*Circle.*"
Epicycloid — ἐπι = "*upon*" + κύλκος.
Hypocycloid — ὑπό = "*under*" + κύλκος.
Involute — (Latin) **in** = "*upon*" + **volvo** = "*to roll.*"

NOTES

A. **Cycloid, Involute, Epicycloid, Hypocycloid.***
These curves belong to the family of **Cycloids.** They may all be defined as *the path traced by a Point on the Circumference of a Circle which rolls on a given Line* (either Straight or Curved).

B. PROBLEM 1. **Cycloid.**
Rolling Circle (**R. C.**) rolls on a *Straight Line.*
(*a*) Take points on initial position of **R. C.**
(*b*) Find successive positions of **R. C.** by making distance **O–1** on **A B** = **arc O–1** on **R. C.**, etc.

In stepping off distances use *small dividers* as shown by PAGE *29*, FIG. *2*.

(*c*) Locate the successive positions of **O** by stepping off the proper arcs in the direction of the arrows.

The length of these arcs will, in each case, be the distance over which the circle has rolled. To verify this, try a coin rolling along the edge of the **T**-square.

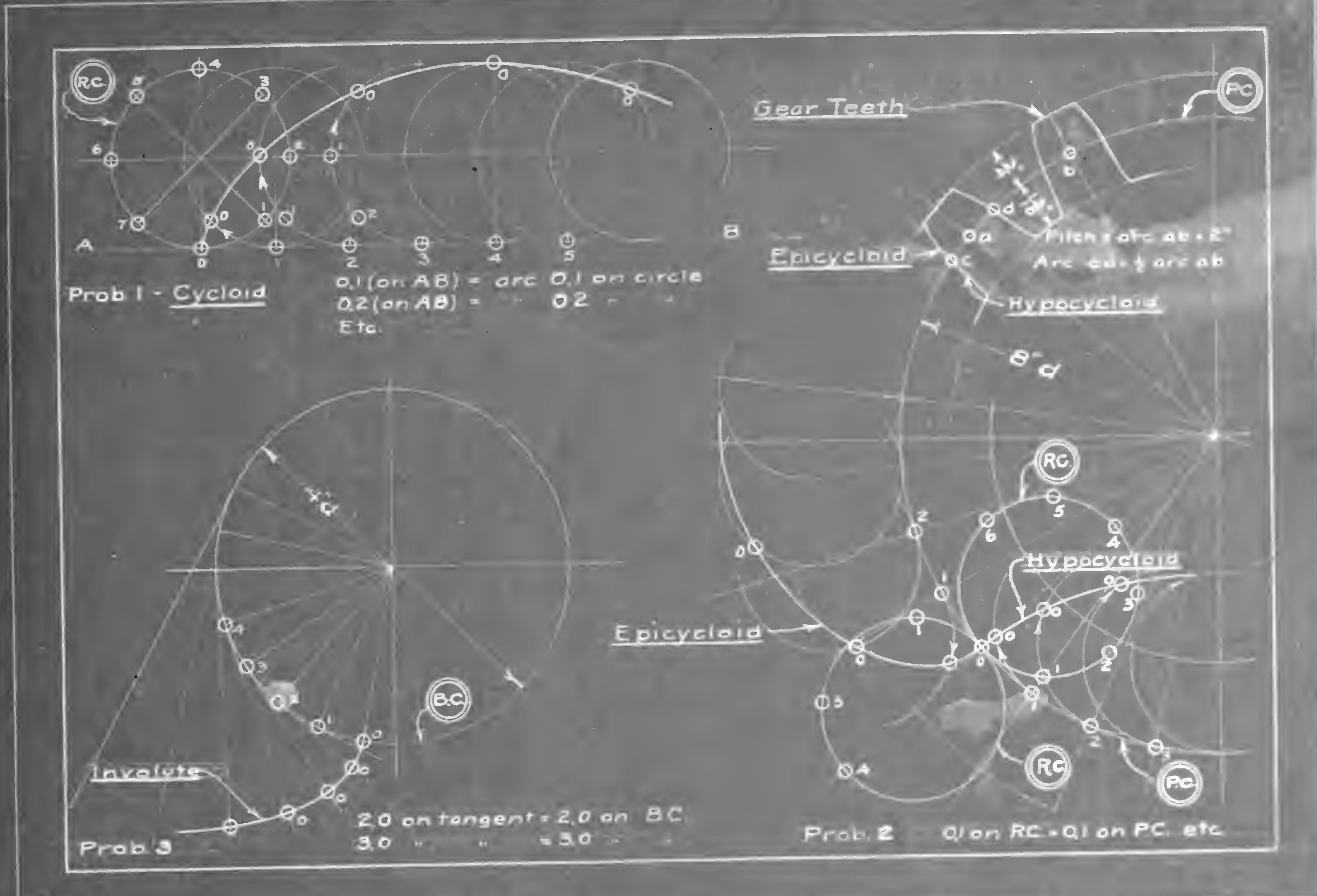
C. PROBLEM 2. **Epicycloid and Hypocycloid.**
Former = **R. C. outside** of another *Circle.*
Latter = " **inside** " "
(*a*) Construct one of each on lower part of Pitch Circle (**P. C.**).
(*b*) Then transfer to upper part of **P. C.** a portion of each curve thus developed to form **gear teeth.** (See PAGE *29*, FIG. *3* for method of transfer.)

Gear teeth are formed by *Epicycloids* and *Hypocycloids* drawn, respectively, *outside* and *inside* a circle known as "**Pitch Circle.**" The "**Pitch**" of the teeth is the distance between the centres of successive teeth, measured along the *Pitch Circle* (arc **a b** in diagram).

D. PROBLEM 3. **Involute.**
Straight Line (Circle of Infinite Radius) rolls on a *given circle.* (Hence a special case of the Epicycloid.)

More simply — a string, held taut, is unwound from a cylinder or drum (represented by given circle). End of string describes *involute.*

The string is taken in successive positions by drawing tangents at end of successive radii, and the proper distances are stepped off as shown. (See PAGE *19* — EX. *2* for method of drawing tangents.)



Note: P.C. = Pitch Circle B.C. = Base Circle RC = Rolling Circle.

4"d means 4 inches diameter

CONTINUE ALL CURVES AS FAR AS POSSIBLE WITHOUT CONFLICT.

Plate 7

PLATE 8

PRACTICE IN STRAIGHT LINES AND ARCS, DIMENSIONING AND CROSSHATCHING, TRACING

LECTURE DATE..

DIRECTIONS

I. Plate *8b* is to be used only to give dimensions. Out of the four objects shown there, a selection will be made.

II. **Order of Pencilling.** (See PAGE *36–1*.)
Stage 1. Block out (Lightly with **6 H** pencil.)
(1) Centre lines, if any.
(2) General size and shape.

This method assists, particularly later on, in gauging the best arrangement of the drawings on a sheet, and prevents unnecessary erasure in correcting the arrangement.

Stage 2. Outlines (**2 H** pencil).
(1) Round the corners. (See Note *A* on this page.)
(2) Strengthen final outline of objects to make ready for dimensions.
Do not erase previous construction.

Stage 3. Dimension Lines (**2 H** pencil).
(1) Lines somewhat lighter than outlines of objects.
(2) *Extension lines* to indicate where the dimension line ends. (See PAGE *36–5*.)
(3) Arrow Heads.

Stage 4. Finish.
(1) Dimension Figures. (See PAGE *36–4*.)
(2) Lettering.
(3) Crosshatching. (See Note *C* on this page.)

When a drawing is to be traced the Crosshatching is often omitted in pencil, or is indicated very briefly by free hand lines.

III. After the sheet is completed, it is to be "checked" in order to verify all information given on it.
(*a*) Apply *four tests* to every dimension.
1. Are the dimension figures correct? (Consult PLATE *8b*.)
2. Does "scale" agree with dimension figure? (Measure distance as drawn.)
3. Are "unit marks" shown? (See *4–a* on PAGE *36*.)
4. Are arrow heads and "extension lines" shown? (See 5 on PAGE *36*.)
(*b*) All statements and specifications should also be verified.
(*c*) Place small check mark (with red pencil) neatly *above* each item found correct. (See PAGE *37*.)
If error is found, correct it before checking.

IV. The pencil sheet will be handed back for a tracing exercise at a date to be announced later.

Directions for Tracing

I. Use *rough side* of tracing cloth.
Rub with *powdered chalk* before inking.

II. **Order of inking.** (See PAGE *36–2*.)
Tracing is simplified by completing one process at a time so as to avoid changing instruments.
Stage 1. Outlines. (BLACK MEDIUM.)

In joining curves and straight lines, best results are obtained by drawing all *curves first*.

Stage 2. Dimension Lines. (RED LIGHT.)
(1) Dimension and Extension Lines.
(2) Centre Lines (if any).

Stage 3. Arrow Heads, Figures, and **Lettering.**
(Use writing pen.) (BLACK.)

Draw light guide lines on tracing cloth in pencil before lettering.

Stage 4. Crosshatching. (BLACK LIGHT.)
Check the tracing as at the end of the pencil work.

NOTES

A. **Accurate Construction** is required.
Method of connecting "tangent" arcs, as shown by PAGE *36–3* should be studied. (See also PAGE *107*.)

The short curves shown on this sheet are often called "**Fillets.**"

B. **Dimensions are Important.**
(*a*) For dimensions in *Quarters*, *Eighths*, *Sixteenths*, etc., use "**Architect's**" Scale.
For dimensions in Decimals use "**Engineer's**" Scale.
(*b*) Dimension figures are preferably made standard size. Best, at first, to draw guide lines for them as for lettering.

C. **Crosshatching.**
(*a*) *Crosshatching* is used to indicate a "**Cross Section**" of an object.
(*b*) It is usually drawn with the **45°** *Triangle*.
Other angles may, however, be used.
(*c*) Space lines about $\frac{1}{16}$ in. apart by *EYE ALONE*.
(*d*) Do not cross Figures or Arrows with hatching lines.
(*To avoid this the Crosshatching is usually added last.*)

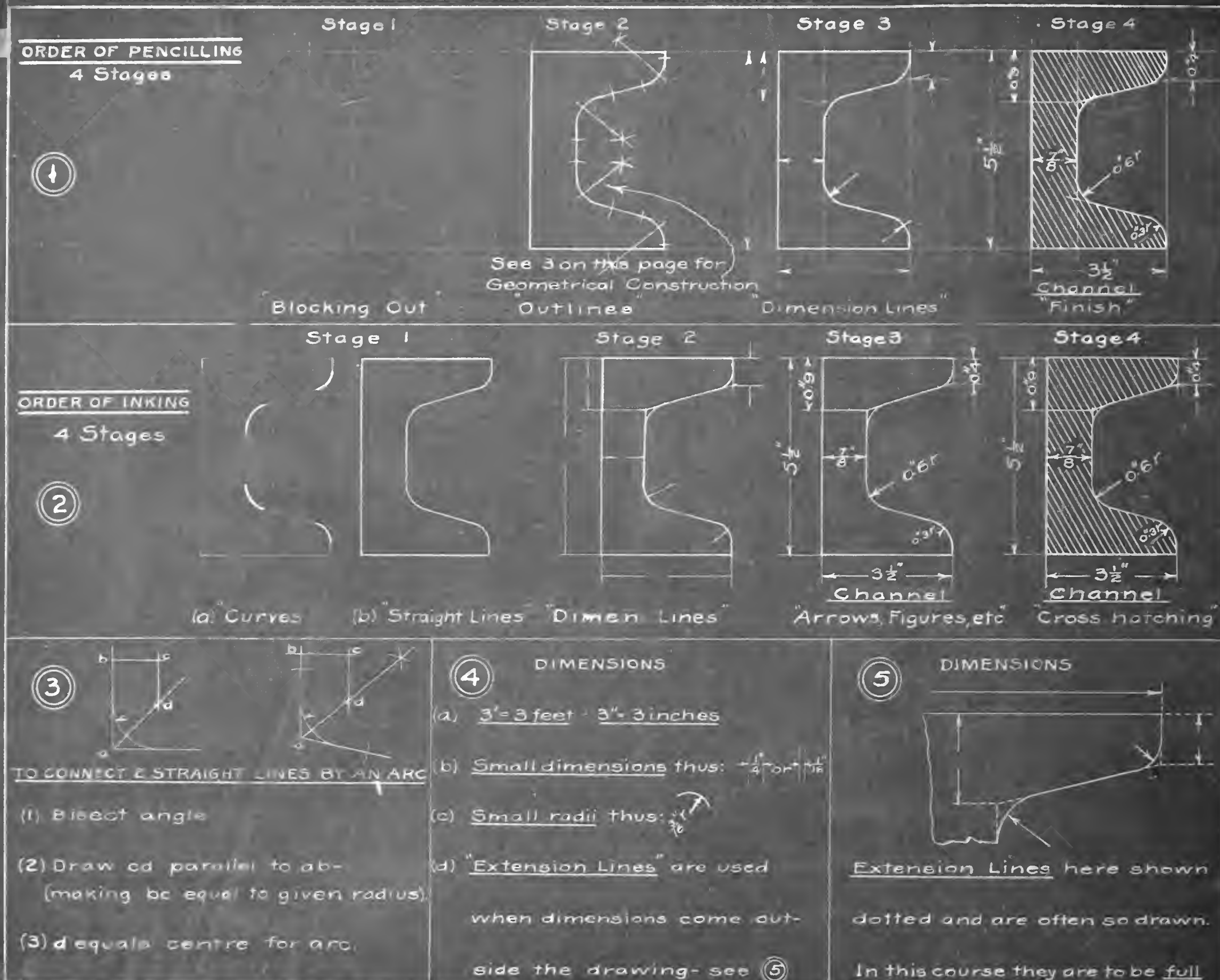
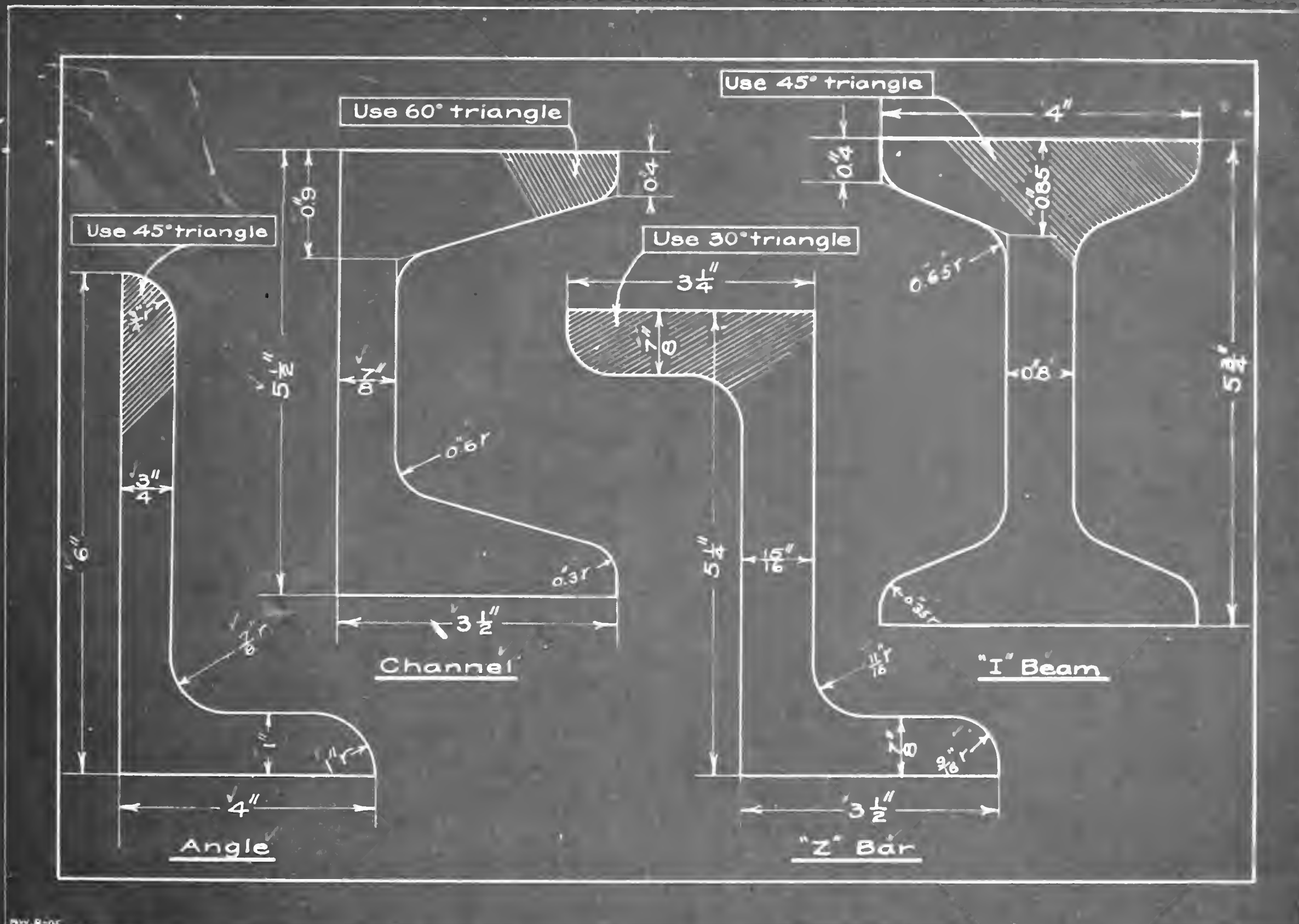

ORDER OF PENCILLING
4 Stages
1
Stage 1
"Blocking Out"
Stage 2
See 3 on this page for Geometrical Construction
"Outlines"
Stage 3
"Dimension Lines"
Stage 4
5½"
3½"
0.6r
0.3r
Channel
"Finish"
ORDER OF INKING
4 Stages
2
Stage 1
(a) "Curves"
(b) "Straight Lines"
Stage 2
"Dimen Lines"
Stage 3
3½"
5½"
7/8"
0.6r
0.3r
Channel
"Arrows, Figures, etc"
Stage 4
3½"
0.6r
0.3r
Channel
"Cross hatching"
3
TO CONNECT 2 STRAIGHT LINES BY AN ARC
(1) Bisect angle
(2) Draw cd parallel to ab– (making bc equal to given radius)
(3) d equals centre for arc.
4
DIMENSIONS
(a) 3' = 3 feet 3" = 3 inches
(b) Small dimensions thus: ¼" or 1/16"
(c) Small radii thus: 3/16"
(d) "Extension Lines" are used when dimensions come outside the drawing – see 5
5
DIMENSIONS
Extension Lines here shown dotted and are often so drawn. In this course they are to be full

Plate 8a



Note: In Tracing (a) Omit all construction lines as shown above.

(b) Light Lines about thus

(c) Medium Lines about thus

(d) Border Line about thus

Plate 8b

LECTURE DATE..

I. **Orthographic Projection,** described simply, is a method of delineating an object accurately and adequately by means of one or more views, so grouped as to be easily read together. The purpose is to give a clear idea of the form and dimensions of the object.

The technical development of **Projection, Projection Planes,** etc., is left for later consideration (see PAGE *117*).

II. EXAMPLE: **House.** (See PAGE *41*.)

(*a*) Let **F. V.** = *Front View*. **R. V.** = *Right Side View*.
T. V. = *Top View*. **L. V.** = *Left Side View*.

(*b*) If we stand far enough away so that the rays from all points of the house to the eye are practically *parallel*, we can reproduce on paper, to a convenient scale, the corresponding appearance of the house.

Place this so-called **View** at the bottom and centre of a sheet of paper and label it **F. V.** (*Front View*).

Now walk around and look at the house from the **Right Side.** Place this *View* to the *Right* of **F. V.** and label it **R. V.** (*Right Side View*).

Similarly place **L. V.** (looking at house from *Left Side*) as shown.

Now look at the house from **above** and place view obtained above **F. V.**, labelling it **T. V.** (*Top View*).

(*c*) Select as an axis of reference the **Centre Line** of the house (*C. L.*).

Note the abbreviations **R** and **L** for *Right* and *Left* of Centre Line.

Note also that any given point on the house has the same number *in all views.*

III. Then **Note Carefully**: —

(1) Point **1** lies on *same horizontal line* in **F. V., R. V.,** and **L. V.**

(2) Point **1** of **T. V.** lies *vertically above* Point **1** of **F. V.**

(3) (Looking at **T. V.** in the direction of arrow **M** and comparing with **R. V.**) Point **1** lies on the *same side* (**Left**) of Centre Line and at *same distance** (**A**) from it in both views.

Similarly (looking in direction **N** and comparing **T.V.** with **L.V.**) — Point **1** lies at distance* (**A**) on the **Right** side of Centre Line in both views.

IV. The above relations constitute the 3 WORKING PRINCIPLES OF ORTHOGRAPHIC PROJECTION. They can be summed up thus: —

(1) The **front** and **side** views of a point on the object lie in the same *horizontal* line.

(2) The **front** and **top** views of the point lie in the same *vertical* line.

(3) The **top** and **side** views of the point lie on *corresponding* sides of the Centre Line (Right or Left) and at the *same distance** from it.

V. (*a*) By means of the above analysis, with *two Views* of an object given, we can usually locate the position of corresponding points in a *third* or *fourth View*, and thus complete these views.

FIG. *4* of PAGE *41* shows method in detail.

(*b*) Any view of an object may be taken as a **F. V.**, but having selected and located this, we must group the other Views about it in accordance with the above principles (**T. V.** always at **Top** — **R. V.** always at **Right**, etc.).

If necessary we could develop a *Bottom View* which would then be placed *below* the **F.V.** (See FIG. 2 on PAGE *41*.)

(*c*) In general, *three Views* are enough to clearly describe an object (as will be seen in example above), but where necessary, *four* or even *five* Views may be taken.

(*d*) *Hidden Lines* are represented dotted, as shown.

(*e*) Note that above principles apply to views of the Lamp (FIG. 3 on PAGE *41*) and to views of points on it.

* Distance is always measured *perpendicular* to Centre Line.

Fig. 1 - House

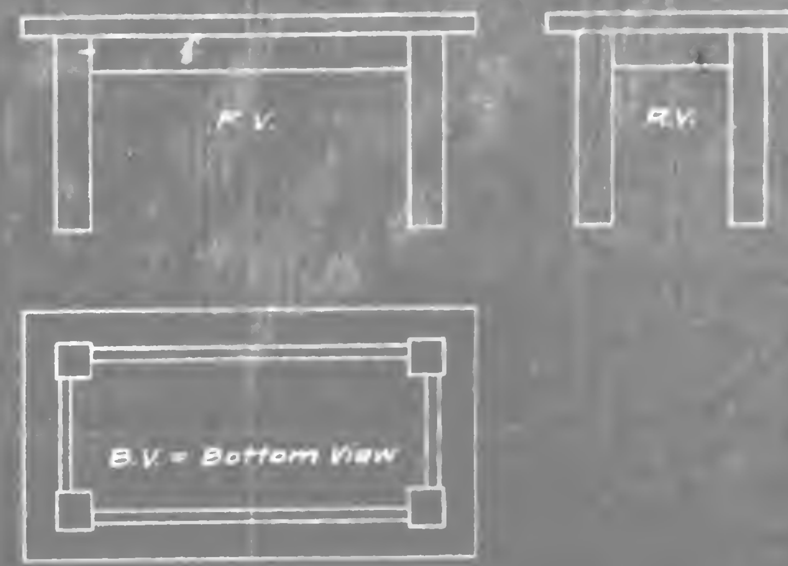


Fig. 2 - Table showing bottom view.

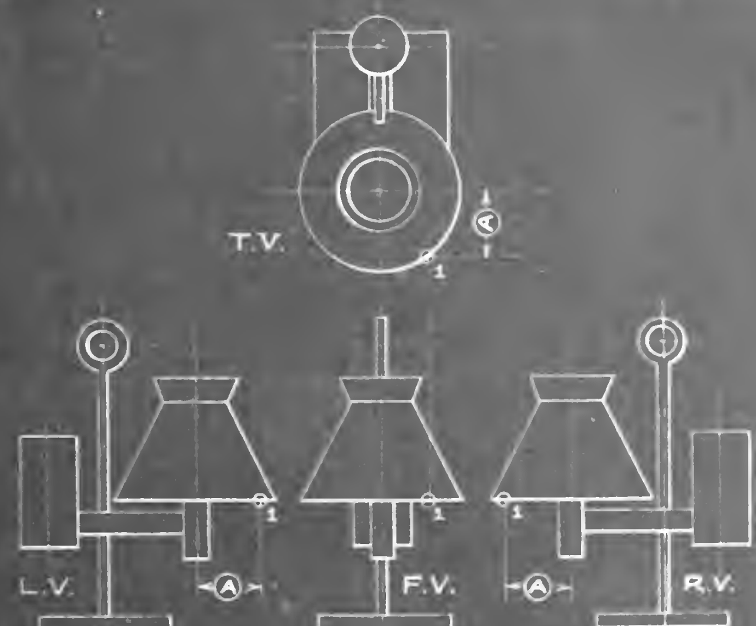


Fig 3 - Lamp

T.V. and F.V. being blocked out, to draw R.V.

(1) Draw lightly lines I and II

(2) In R.V. set off, from ℄, distances III, IV, V and VI obtained from T.V.

(3) Join points with lines VII, VIII, IX

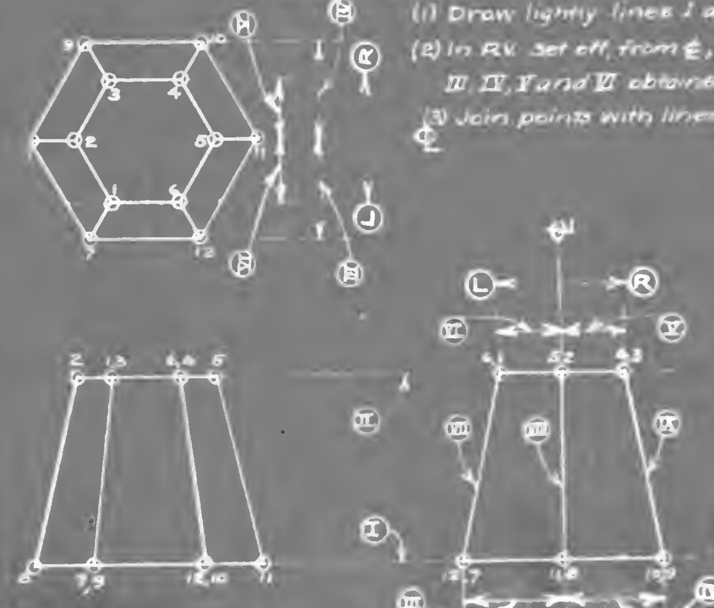


Fig 4 - Two views given, to draw third.

LECTURE DATE..

DIRECTIONS

I. From the problems here given, a selection will be made and announced at the lecture.

II. Adapt the **Order of Penciling** as given on PAGE *34* to these sheets thus: —

Stage 1. (*a*) Layout Centre Lines to locate positions of Views.

Centre Lines are not restricted to **T.V.** and **R.V.** but are drawn at the outset in any view that is in general symmetrical. Subordinate parts (if symmetrical) also have Centre Lines.

(*b*) *Block out* all Views of the objects lightly.

As far as possible, develop all views of an object together instead of completing one view before beginning another. For instance: Where a horizontal line is to appear in **F.V.** and **R.V.** or **L.V.** draw it, at one stroke, through both views. Similarly for vertical lines in **F.V.** and **T.V.**

This will be found to economize time and to assist in understanding the relation of the various views.

Stage 2. Strengthen *outlines*, drawing visible lines *full*, and hidden lines *dotted.*

When blocking out, draw hidden lines light and full: a light "*d*" placed on them will indicate that they are to be dotted later.

Stage 3. *Dimensions* are to be omitted on these sheets.

Stage 4. Put in *Lettering*, etc.

III. Ink in: —

(*a*) All centre lines (*Red-light*).

(*b*) Border line (*Black-heavy*).

PROBLEMS

Study carefully PAGES *40* and *41*. Apply principles there explained to the development of the problems given on PLATE 10.

PROBLEM 1. Given **F.V.**, **T.V.**, and **R.V.** of house, draw **L.V.**

PROBLEM 2. Given **F.V.**, **T.V.**, and **L.V.** of object, draw **R.V.**

PROBLEM 3. Given **F.V.**, **T.V.**, and **R.V.**, draw **L.V.**

PROBLEM 4. Suppose the object of PROBLEM 3 be turned on its base through an angle of 30°. Draw the **T.V.**, **F.V.**, **R.V.**, and **L.V.** of the object in this position.

PROBLEM 5. Given **F.V.**, **T.V.**, and **L.V.**, draw **R.V.**

PROBLEM 6. Object of PROBLEM 5 turned 30° on its base. Draw **T.V.**, **F.V**, **R.V.**, and **L.V.**

Questions for Consideration

(1) **T.V.** of an object is represented by a circle inside of a square. What different *front views* are consistent with this **T.V.**?

(2) **F.V.** of an object consists of three concentric circles. What *side views* can be drawn?

(3) With the inmost circle *dotted*, what *side views* can be drawn?

(4) Can any view of a curve be a straight line?

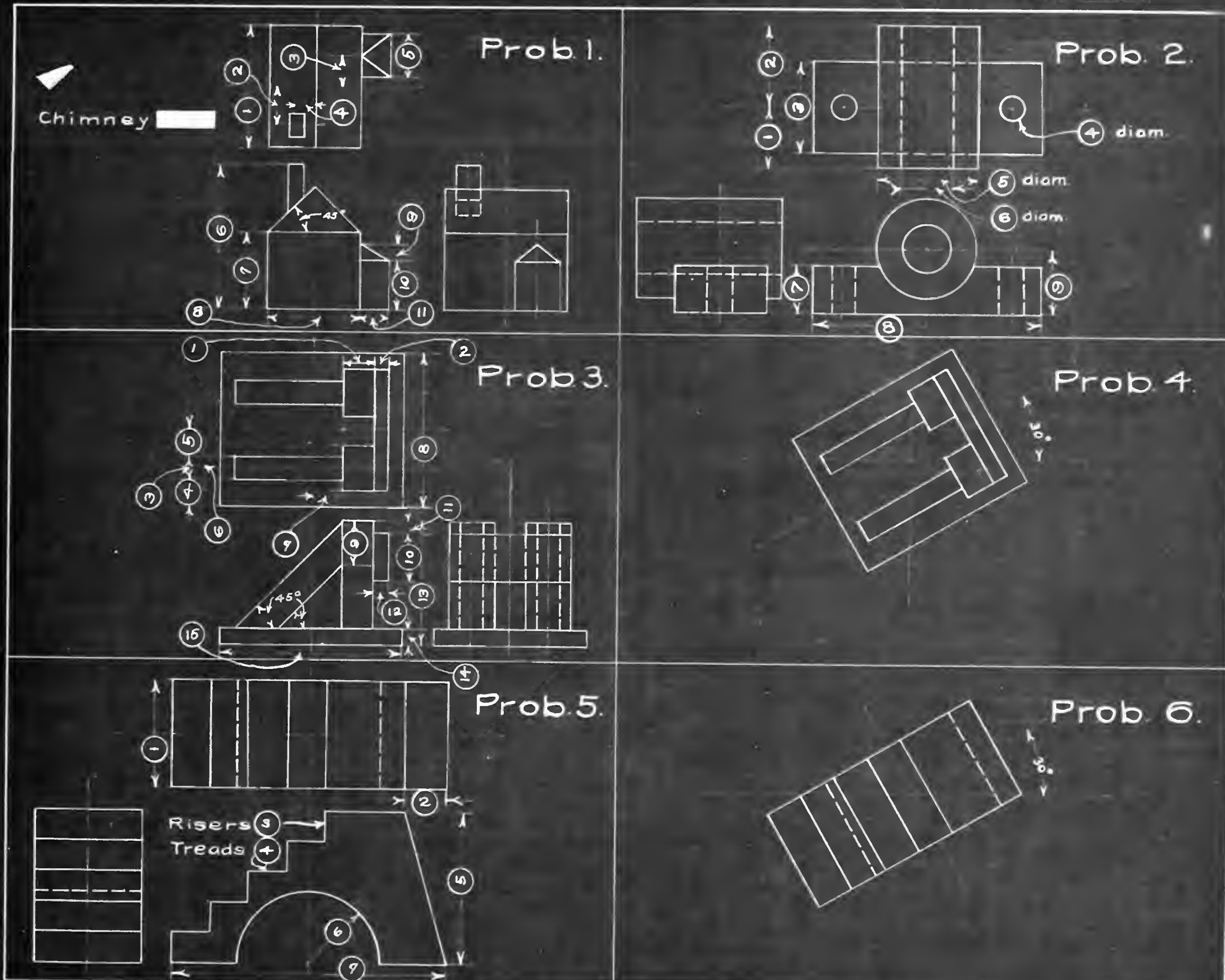

Prob. 1.
Chimney
45
Prob. 2.
diam.
diam.
diam.
Prob. 3.
45°
Prob. 4.
30°
Prob. 5.
Risers
Treads
Prob. 6.
30°

Plate 10

PLATE 11

ORTHOGRAPHIC PROJECTION — TRUE SIZES AND TRUE LENGTHS (*continued*)

LECTURE DATE.. ......

PLATE 11

ORTHOGRAPHIC PROJECTION — TRUE SIZES AND TRUE LENGTHS

DIRECTIONS

I. Procedure same as for last plate.

(*a*) Lay out *Centre Lines.*

It is best to lay out also Centre Lines of symmetrical parts like the chimney (see distance **A**) so that points on it (**1** for instance) can be set off equal distances right and left of its own Centre Line.

(*b*) Block out all 4 Views together. (**Stage 1.**)

(*c*) Strengthen Outlines of all 4 Views. (**Stage 2.**)

In the blue print all lines have been drawn *full.* Remember that HIDDEN LINES should be *dotted.*

In strengthening, therefore, correct the lines of the blue print wherever necessary.

(*d*) Draw Dimension Lines and Arrows. (**Stage 3.**)

(*e*) Put in Figures and Lettering. (**Stage 4.**)

II. Draw in addition to views shown on plate: —

(*a*) *Left Side* View.

(*b*) *True Size* of end roof.

(*c*) *True Size* of back roof, including hole for chimney.

III. INK IN, as hitherto: —

(*a*) Centre lines. (*Red-light.*)

(*b*) Border line. (*Black-heavy.*)

NOTES

A. (*a*) Use edge of Scale marked "$\frac{1}{4}$." This gives graduations corresponding to $\frac{1}{4}$ *inch* = **1** *foot*, which is the Scale called for in the drawing.

(*b*) **18′–3″** means **18** *feet*, **3** *inches*, etc.

B. Walls are considered as having no thickness, and *Door* and *Window* as open.

C. The *True Size* of a slanting plane is shown by a view taken in a direction perpendicular to the plane.

For example the true size of front roof is seen looking in direction **S.**

The required distances used in building up a "*True Size*" can be taken from any view where these distances are seen in their *true lengths.*

Questions for Consideration

(1) In getting *true size* can all the distances come from one view? Why?

(2) What kind of a view must be taken to see a line in its *true length?*

(3) How could the *true length* of the hip rafter (**2–3**) be found without drawing the true size of the whole roof?

(4) Under what conditions can a *view* of a line be (*a*) shorter than, (*b*) equal to, (*c*) longer than, the line itself.

(5) What is the shortest view a line can have?

(6) As suggested by questions 4 and 5, what are the limiting cases of the views of a plane surface, say a rectangle?

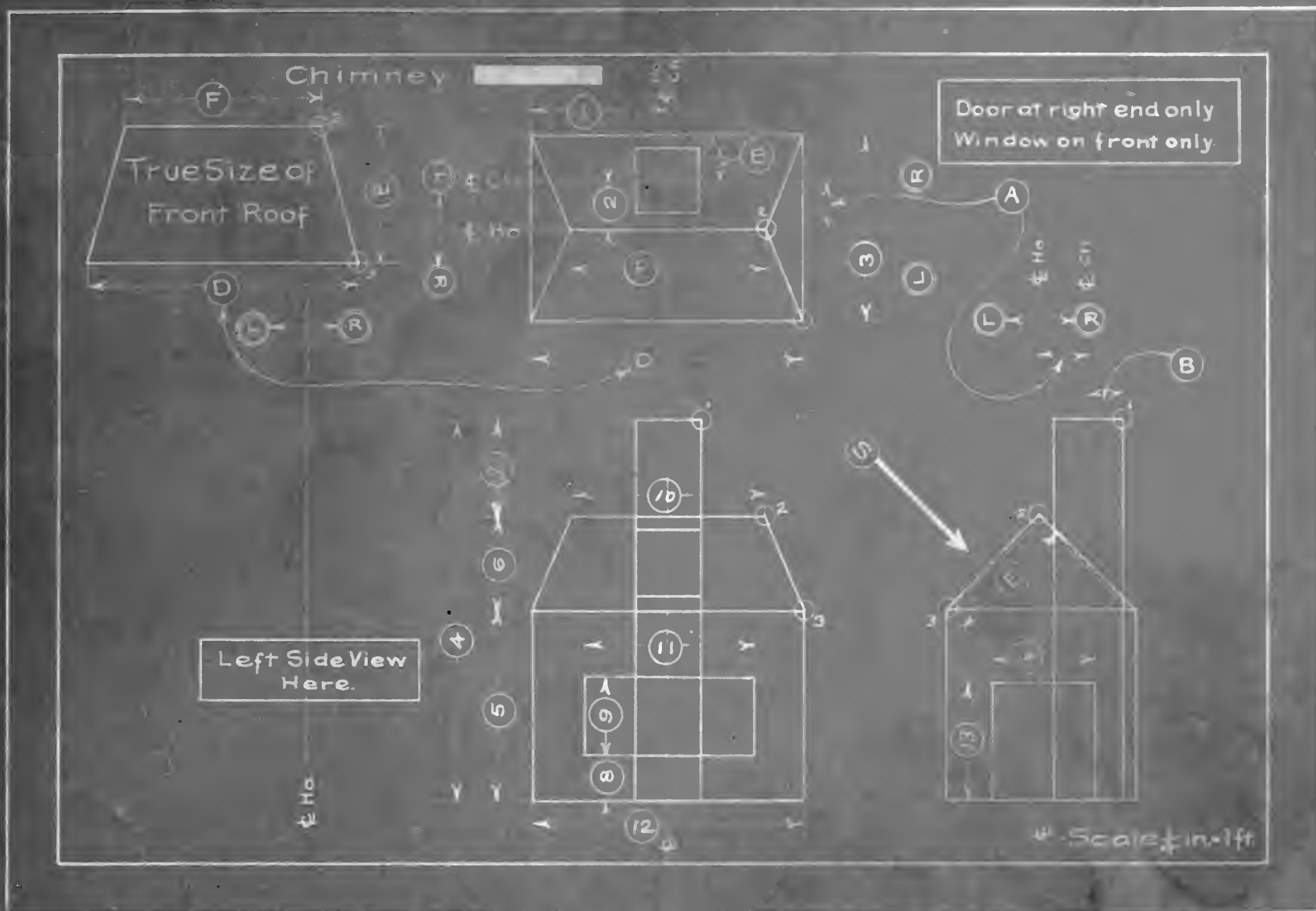

Chimney
True Size of Front Roof
Door at right end only
Window on front only
Left Side View Here.

Plate 11.

LECTURE DATE........

DIRECTIONS

I. Follow directions for last plate.

II. Substitute for "?" the proper dimension figures taken from Plate 11.

Note that the location of some dimensions has been changed, as a line should **only be dimensioned where it appears in its True Length.**

III. Inking. Same as hitherto.

NOTES

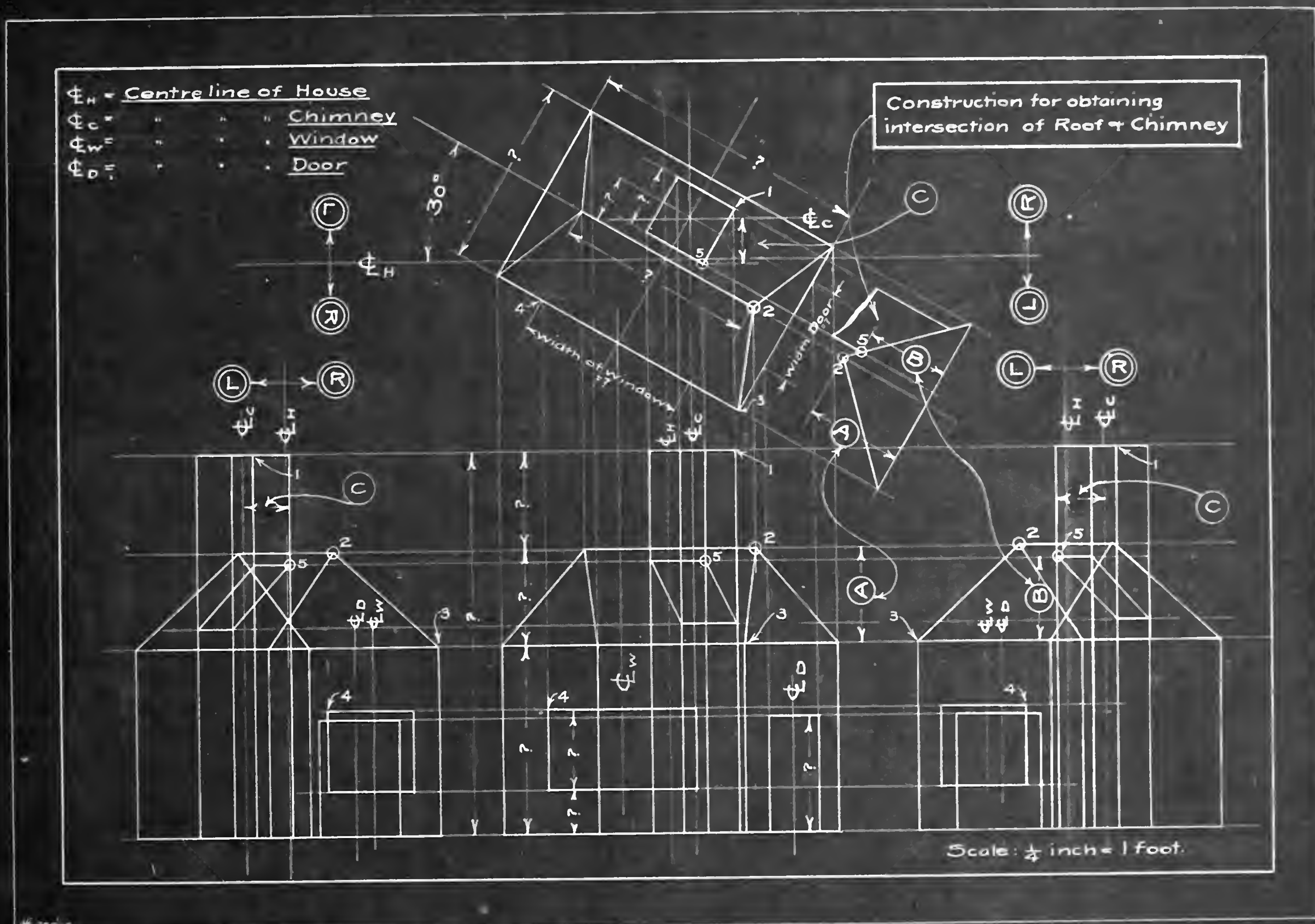
A. This sheet shows the subject of Plate 11 turned through an angle of 30°.

B. Remember, as before, that *Hidden Lines* are to be shown *dotted.*

Questions for Consideration

(1) With views as here given, how would you find the true length of the hip rafter (**2–3**)?

(2) How would you find the true size of end and side of roof and of hole in roof?



Note: Be careful to note whether or not corresponding reference points are correctly located and numbered in above print. If any correction is necessary, make it in red ink on the blue print.

Plate 12

PLATE 13

INTERSECTION OF PRISM AND PYRAMID BY PLANE—DEVELOPMENT

LECTURE DATE..............................

INTERSECTION OF PRISM AND PYRAMID BY PLANE—DEVELOPMENT

FROM NOW ON, WITH THE EXCEPTION OF THE PLATE ON ISOMETRIC DRAWING, ALL THE PROBLEMS OF THE COURSE ARE BASED ON THE PRINCIPLES OF ORTHOGRAPHIC PROJECTION. THIS TERM WILL, THEREFORE, BE OMITTED FROM THE HEADINGS, AND THE TITLE ONLY OF THE SPECIAL PROBLEM WILL BE GIVEN.

DIRECTIONS

I. For both problems.

(*a*) Number neatly every point of the object *in all views* and in Development, for purposes of identification during construction.

(*b*) Inking same as hitherto.

(*c*) After drawing the *Development*, reproduce it on a piece of stiff paper, cut out and fold to produce original object.

II. PROBLEM 1. **Intersection of Prism by Plane.**

(*a*) Work out *Front*, *Top*, and *Side Views* of the prism as it appears before it is cut off.

(*b*) Across **F.V.** draw a line representing the *Cutting Plane* and find the resulting **Intersection.**

The *Side View* of the Intersection (5–10–11–12) can be found thus:—

The Cutting Plane cuts* the edge **2–6** at **10** (**F.V.**). Identify point **10** on **2–6** in **R.V.** (See PAGE 40–IV–1). Similarly obtain points **5, 11,** and **12** in **R.V.** and join them as indicated.

(*c*) Obtain *True Size* of Intersection (see Plate 11).

(*d*) Draw a **Development** of that part of the surface of the Prism which is below the Cutting Plane. (See Note A on this page.)

III. PROBLEM 2. **Intersection of Pyramid by Plane.**

(*a*) Show first the Pyramid as it appears before it is cut off.

(*b*) Then draw *Cutting Plane* and find the resulting *Top* and *Side Views* of the Intersection.

Find at what point each edge is cut* off by the Cutting Plane in **F.V.** Then identify these points on the corresponding edges in **T.V.** and **R.V.** by principles of PAGE 40–IV–1 and 2. Join the points thus found to show Intersection.

(*c*) Obtain *True Size* of Intersection.

(*d*) Draw *Development* of that part of the Surface of the Pyramid which is *below* the Cutting Plane. (See Note B on this page).

* The point where an edge is cut off must first be found in a view where the Cutting Plane is seen "edgewise" and appears as a straight line. This line is called a "*trace*" of the plane.

NOTES

Given an object, like an irregular Box, to find the *size* and *shape* of a *sheet of material* which, when folded, will produce the object.

The solution of this problem is indicated on this sheet. The technical term by which this process is known is:—

Development of a Surface

Method: Build up the **Development** line by line, taking distances from any view where the lines are seen in their *true length.*

A. **Prism.**

True length of upright edges found in **F.V.** or **R.V.** (Distance = **B**).
True length of edges of base found in **T.V.** (Distance = **M**).

B. **Pyramid.**

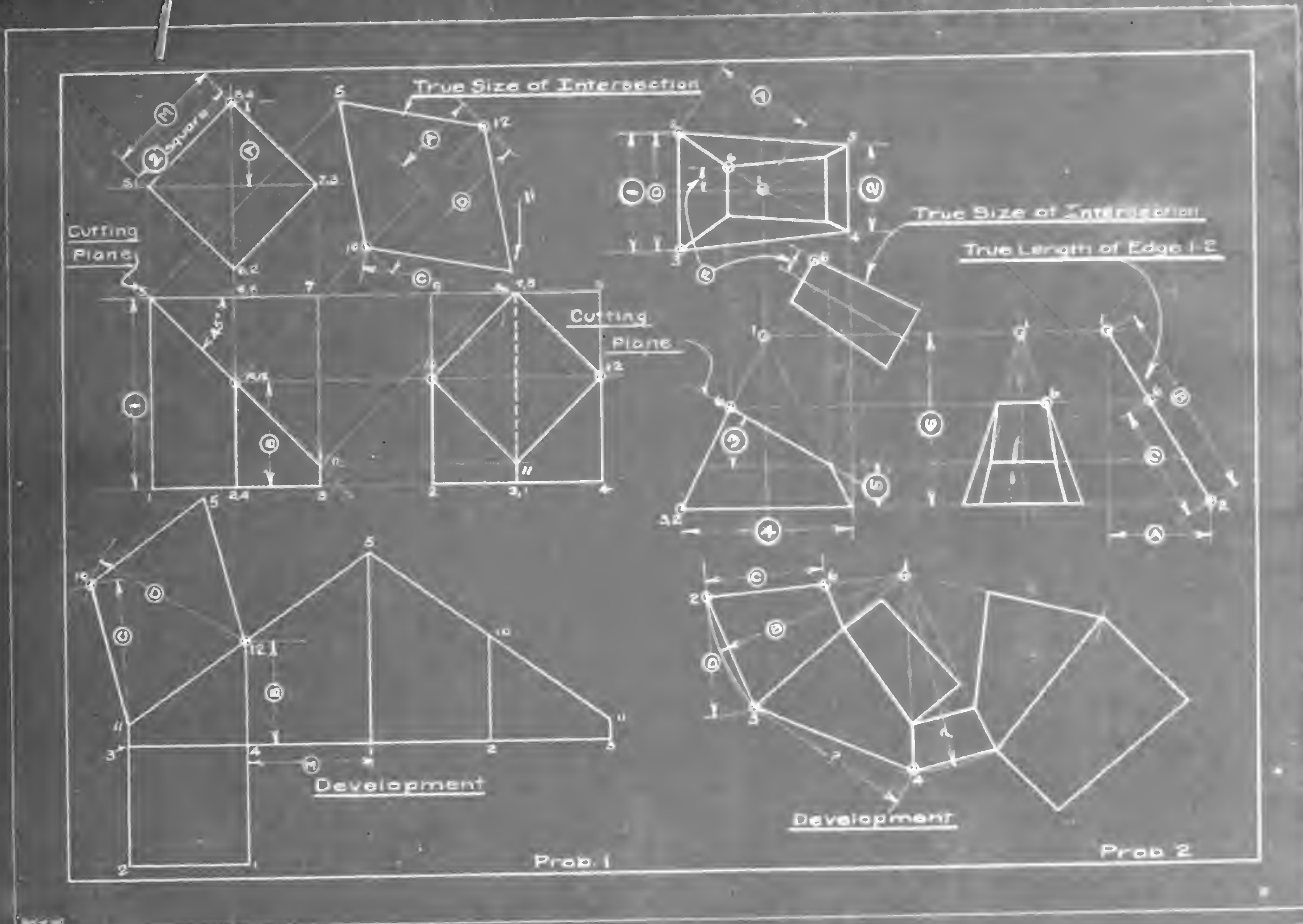
(*a*) Principle same as for Prism but note that none of the three given views shows the slanting edges of the Pyramid in their *true length* as needed for the Development.

(*b*) To be seen in its "*true length*" a line must be perpendicular to the direction of sight. Hence "revolve" the line into such a position.

(*c*) Method as follows: (*See diagram at bottom of* PAGE 57).
Let **ab** = **F.V.** of given Line.
" $\mathbf{a^1b^1}$ = **T.V** " "
Suppose it is desired that **F.V.** shall show true length.
Revolve bottom ($\mathbf{b^1}$) of line to ($\mathbf{c^1}$). (Thus the whole line is revolved.)
ac will then be **True Length** of the line.

(*d*) More simply by using distances **A** and **B** in connection with altitude as shown for the edge (**1–2**).

The 60° Triangle will serve as a model of the above. As it stands vertically on the table, the "long," "short," and hypothenuse sides represent respeetively the altitude, distance **A**, and true length.


True Size of Intersection
Cutting Plane
Cutting Plane
2 square
45°
Development
Prob. 1
True Size of Intersection
True Length of Edge 1-2
Development
Prob. 2

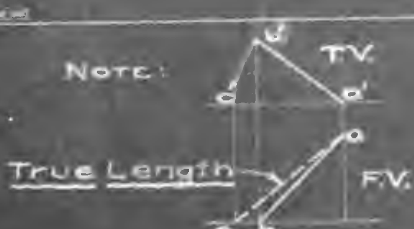

Note:
T.V.
F.V.
True Length

Plate 13

PLATE 14

INTERSECTION OF CYLINDER AND CONE BY PLANE—DEVELOPMENT

LECTURE DATE..

PLATE 14

INTERSECTION OF CYLINDER AND CONE BY PLANE—DEVELOPMENT

DIRECTIONS

PROBLEM 1. **Cylinder.**

(*a*) Draw three views of Cylinder full height as it appears before it is cut off and locate *Elements*.

Use as many elements as are found necessary to draw *accurately* and smoothly the curve of intersection. They can be lettered, as indicated, for convenience of identification during construction. (See *a*, *b*, *c*, etc., in blue print.)

(*b*) Across **F. V.** draw a line representing the *Cutting Plane* and find resulting *Side View* and *True Size* of Intersection.

Identify points where elements are cut off by Cutting Plane.

(*c*) Draw **Development** as indicated.

PROBLEM 2. **Cone.**

(*a*) Proceed as in Problem 1, finding also the *Top View* of Intersection.

(*b*) To Construct the **Development**.

(1) Lay out arc with radius = true length of elements. (Since all points of the base are at the same distance from the vertex.)

(2) On this step off distances **3–4**, etc., from **T. V.** (Total length of arc is, of course = circumference of base.)

(3) Lay off on each element the true lengths **E**, **F**, etc., and draw curve.

The *true length* of an element is evidently the distance **D** in **F.V.** The true length of **1–6**, then, will be **E**; of **2–7** will be **F**, etc. (See PAGE *56–B–b*, *c*, and *d*.)

* The point where an Element is cut off must first be found in a view where the Cutting Plane is seen "edgewise" and appears as a straight line. This line is called a "**trace**" of the plane.

NOTES

A. If a cylinder or cone is cut off by a plane the "**Cutting Plane**" will intersect the surface of the object in a curve, successive points of which can be found thus:

(*a*) In order to carry out a construction on any curved surface like these, we must first locate certain lines lying in the surface in such a way that they can readily be identified in all views, and then *upon these lines* work out the required construction.

To obtain such lines in the surface of the cylinder, we can use *vertical* "**Auxiliary Planes**" through its axis. These will cut in the surface of the cylinder straight lines which run vertically from points in the base circle and can thus be identified in all views. These lines are called "**Elements.**"

In the case of the Cone, similar auxiliary planes will cut straight line elements which run from points in the base circle to the vertex.

(*b*) The problem now becomes simply to find at what point* each *Element* is cut off by the Cutting Plane, and then to identify this point in the other views. By joining consecutive points found in this way we draw the required curve of intersection.

B. The Cylinder may be considered as a Prism (and the Cone a Pyramid) of an infinite number of sides. In both cases:

(*a*) The base polygon becomes a circle.

(*b*) The surface between the edges becomes the smooth Cylindrical or Conical Surface.

(*c*) The edges become the Elements.

C. Hence the method of construction, after the Elements are located, follows closely that given for the Prism and Pyramid of Plate 13.

D. As long as the *Cutting Plane* passes entirely *across* Cone, any angle ϕ will give an *Ellipse*.

Questions for Consideration

(1) What is (*a*) the *smallest* (*b*) the *largest* value of ϕ to still give an ellipse? With these limiting values what curves are produced?

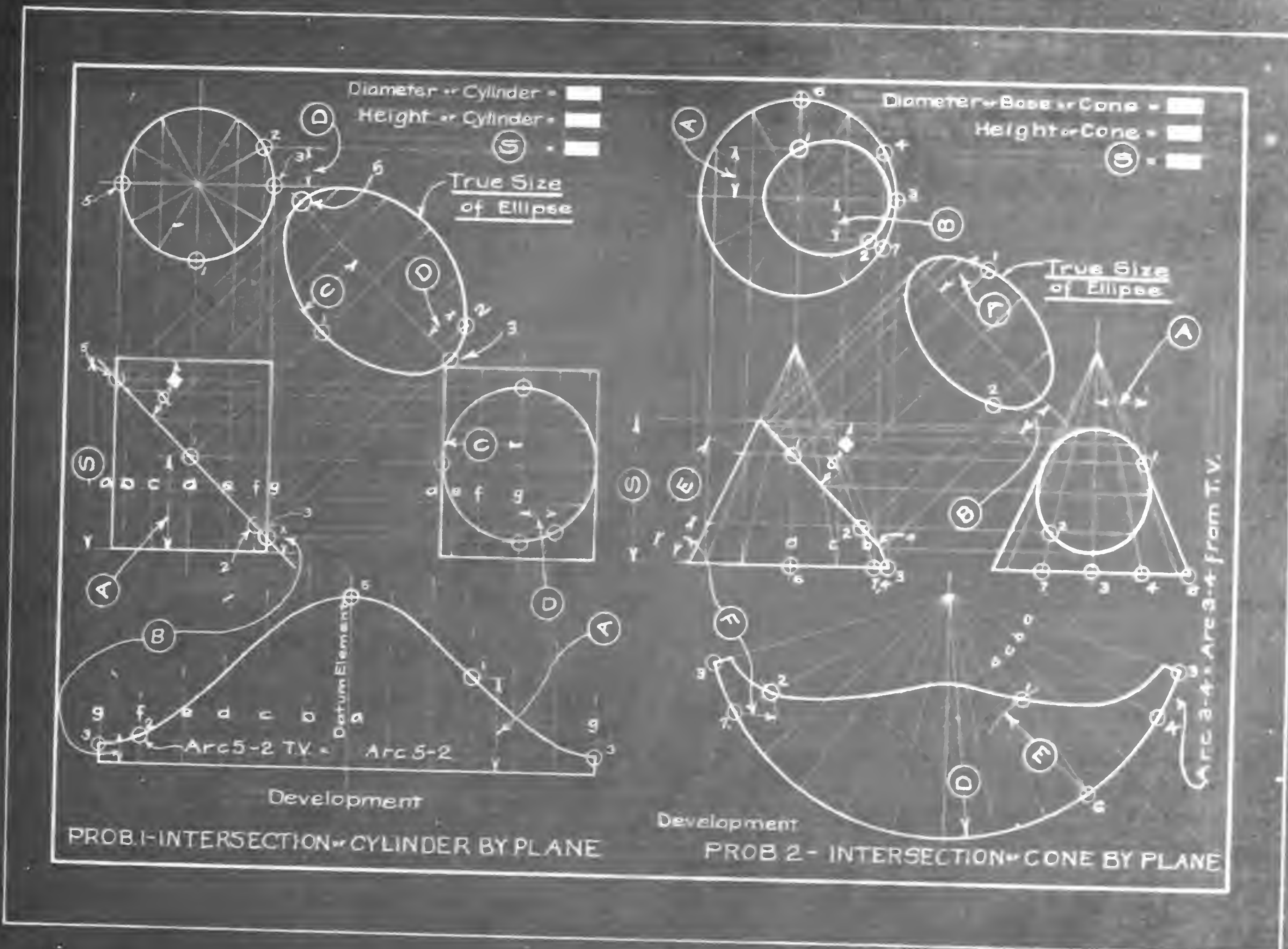

Diameter of Cylinder =
Height of Cylinder =
True Size of Ellipse
Datum Element
Arc 5-2 T.V. = Arc 5-2
Development
PROB. 1 - INTERSECTION of CYLINDER BY PLANE
Diameter of Base of Cone =
Height of Cone =
True Size of Ellipse
Arc 3-4 = Arc 3-4 from T.V.
Development
PROB. 2 - INTERSECTION of CONE BY PLANE

Plate 14

LECTURE DATE..

DIRECTIONS

I. Draw outlines of Cone in **F.V.**, **T.V.**, and **L.V.**

II. Show on **F.V.** the 4 **Cutting Planes** which produce the circle, ellipse, etc.

III. Construct **T.V.** and *True Size* of each intersection by means of **Auxiliary Planes.** (See note B.)

As many Auxiliary Planes can be used as found necessary.
In this problem they may be taken about $\frac{1}{4}$ inch apart on **F.V.** with an extra one near the ends of ellipse, etc., to give smooth curves.

COMPLETE ALL THE CURVES.

Questions for Consideration

(1) Could the method of Plate 14 be applied to the solution of this sheet, and *vice versa?*

(2) What are the advantages and disadvantages of each method?

NOTES

A. *Planes* cutting the *Surface of a Cone*, at different angles, produce corresponding curves of intersection, called "**Conic Sections,**" as suggested on opposite page.

(*a*) *Plane parallel to axis of Cone*— **Hyperbola.**

(*b*) " " " *slanting Element*— **Parabola.**

(*c*) " *crosses Cone*— **Ellipse.**

(*d*) " *perpendicular to axis*— **Circle.**

In the case of the *Hyperbola* we get *two curves*, the second one inverted, if we consider the plane to cut the Cone produced above the vertex.
Further consideration of *Conic Sections* is left for Analytic Geometry.

B. (*a*) As in Plate 14, a curve of intersection cannot be found until lines lying in the surface of the cone have been located and identified in all views.

To do this we again use *Auxiliary Planes*, this time *perpendicular* to the axis of the cone, and obtain *circles* as the required lines. Note that the circle given by Auxiliary Plane P is seen in **T.V.** in its true size, but appears in **F.V.** as a straight line. (See bottom of PAGE 65–FIG. 1.)

(*b*) The construction for finding the points where the Cutting Plane cuts through these lines and joining these points for the required curve follows the method of Plate 14.

The points are first found in **F.V.** (see note at bottom of PAGE 60), then identified in **T.V.** and in *true size*.

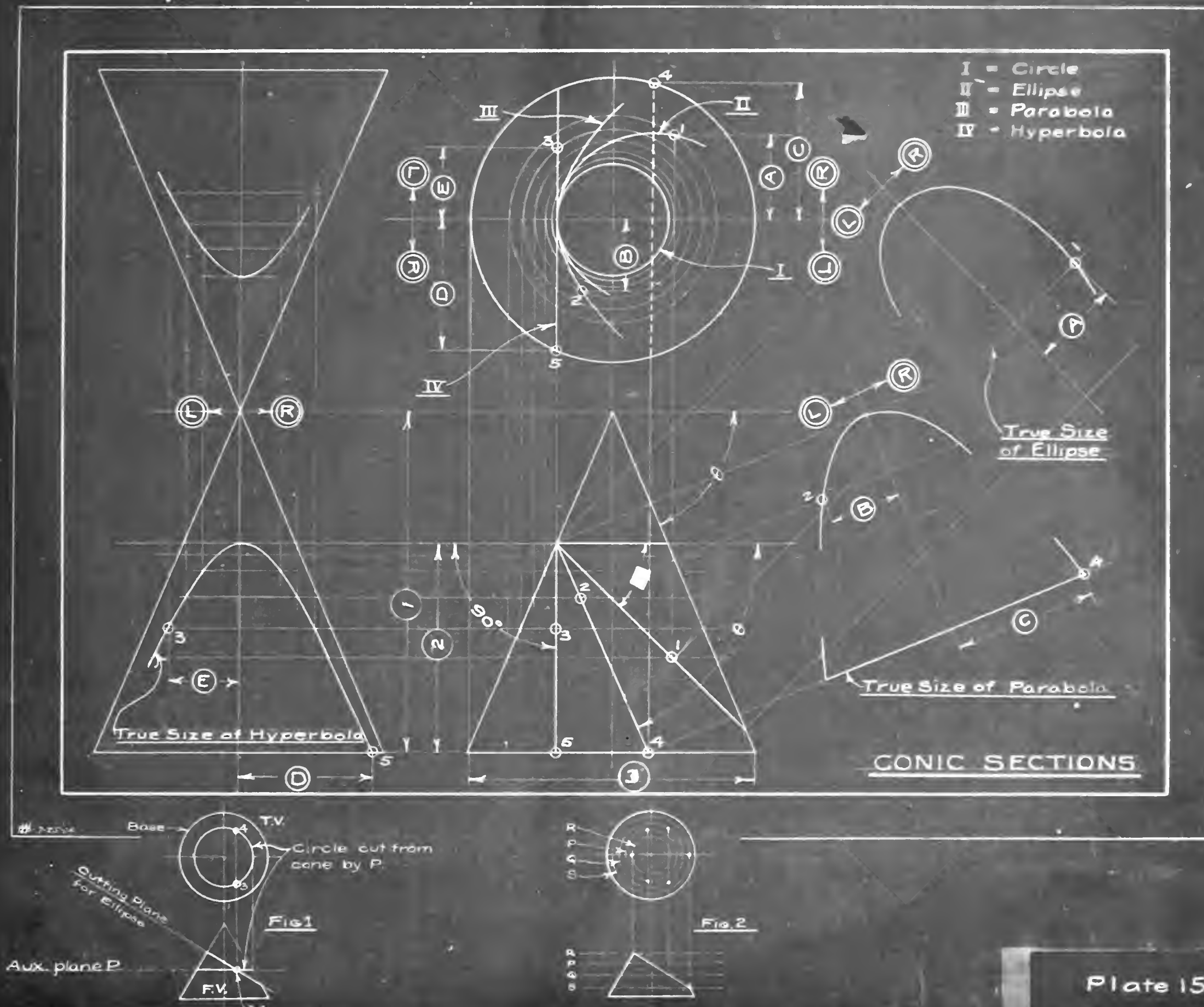

I = Circle
II = Ellipse
III = Parabola
IV = Hyperbola
True Size of Ellipse
True Size of Parabola
True Size of Hyperbola
CONIC SECTIONS
Base
T.V.
Circle cut from cone by P.
Cutting Plane for Ellipse
Fig 1
Aux. plane P
F.V.
Fig. 2

Plate 15

INTERSECTION OF CONE AND HEXAGONAL PRISM—NUT FOR BOLT

LECTURE DATE.........

PLATE 16

INTERSECTION OF CONE AND HEXAGONAL PRISM—NUT FOR BOLT

DIRECTIONS

I. (*a*) Method of construction indicated on blue print. (As in *Conic Section* plate we use *horizontal* Auxiliary Planes.)

Roman Numerals show *order* of construction.

(*b*) Draw **complete hexagon** in *Top View*. (See PAGE 19, Ex. 1, for construction of hexagon.)

II. At a later date this sheet is to be *traced*.

(*a*) Use **Shade Lines** on all views, in accordance with principles given on PAGE *109* (*on Tracing only*).

(*b*) Omit all *Construction Lines* on the tracing.

(*c*) **Order of Inking.**

On the tracing the **F.V.** can be made over into a "*half-section*," as shown at bottom of blue print (PAGE 69).

Stage 1. Outlines. (*Black.*)

It is more convenient to draw first all unshaded lines; then open pen a little and draw all shaded lines.

Stage 2. Dimension lines. (*Red-light.*)

Dimension and Extension Lines.
Centre Lines.

Stage 3. Arrow heads, Figures, and Lettering. (*Black.*)

Stage 4. Crosshatching.

NOTES

A. The curve developed on the *Front Face* is evidently a portion of an **Hyperbola.**

The same curve appears on the slanting faces, in both front and side views, but in both cases more or less foreshortened.

B. Nuts thus cut off are said to be "**chamfered.**"

C. **F. V.** shows the nut "across *corners*."
R. V. " " "across *flats*."

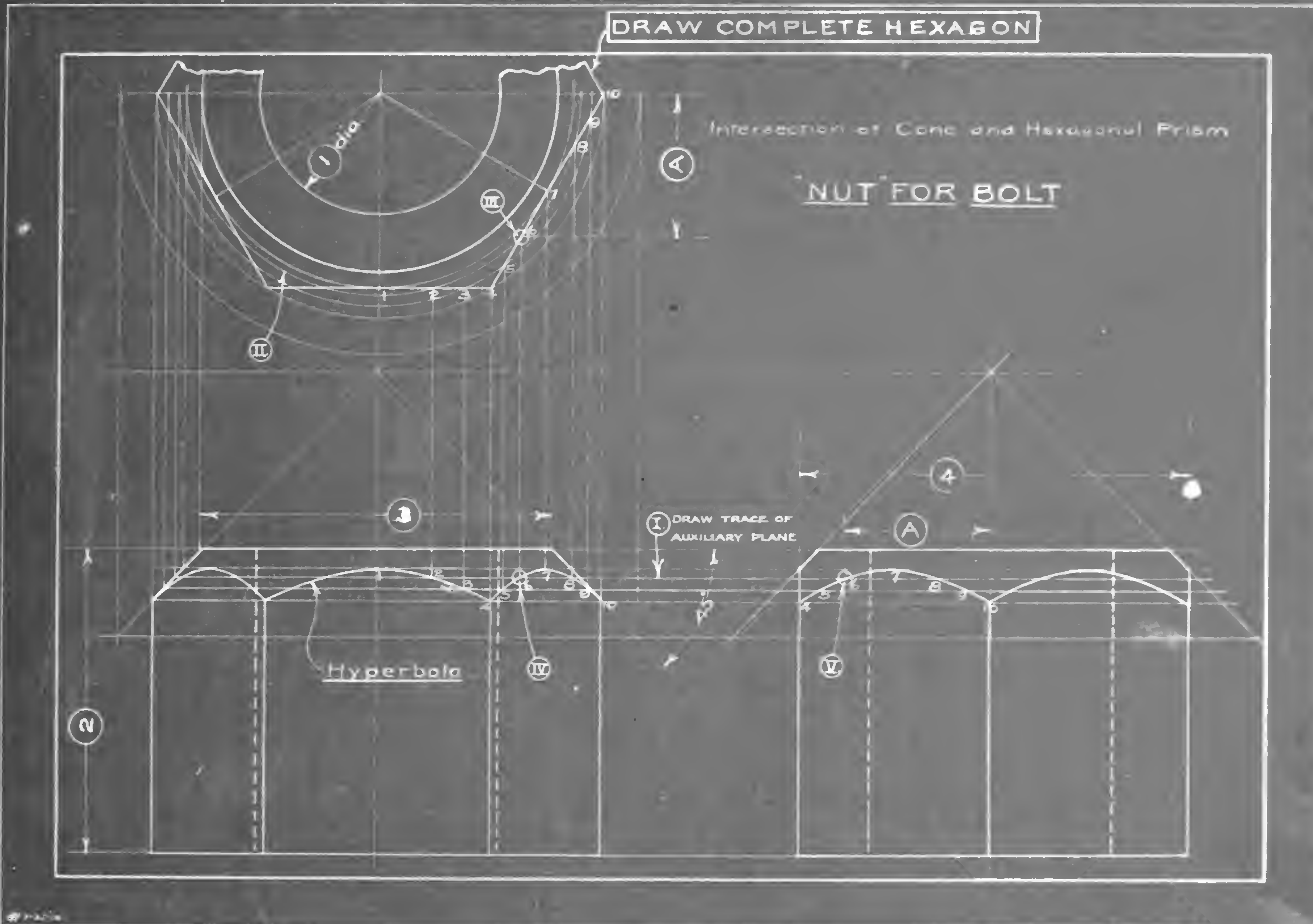
Questions for Consideration

(1) Sometimes the nut is cut off at the level of the tops of the curves. How does that change the 3 views?

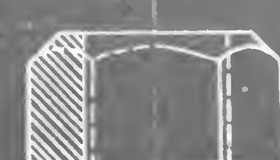
(2) Suppose, instead of being hexagonal, a nut were square (see PAGE 113–V), what would the resulting curves be?

(3) If, instead of being chamfered, a nut were "rounded" (*i. e.* Cone is replaced by Sphere), what would the resulting curves be?

(4) How would you construct the curves of 2 and 3?



NOTE. (a) Roman numerals show order of construction
(b) "Half Section" in Front View would appear thus:



LECTURE DATE

PLATE 17

INTERSECTION AND DEVELOPMENT OF PENTAGONAL AND TRIANGULAR PRISMS

DIRECTIONS

(1) Block out the 3 Views of the Pentagonal and Triangular Prisms (both Equilateral).

Use identifying numbers for corners of the object.

(2) Work out **F.V.** of *Intersection*.

(3) Draw Developments as indicated.

(4) Substitute for "**?**" in Developments the proper dimensions taken from the corresponding lengths in the original views.

(5) Reproduce Developments on piece of Duplex Paper; cut out and fold to produce original subject.

Questions for Consideration

(1) Under what assumption is the line **11–13** in **R.V.** full.

(2) " " " could it properly be dotted?

(3) Suppose the triangular prism were inclined (say 30° to the horizontal), how would you find the intersection?

NOTES

A. Method of constructing *Intersection*.

(*a*) In turn consider each *edge* of one prism as intersected by a plane of the other.

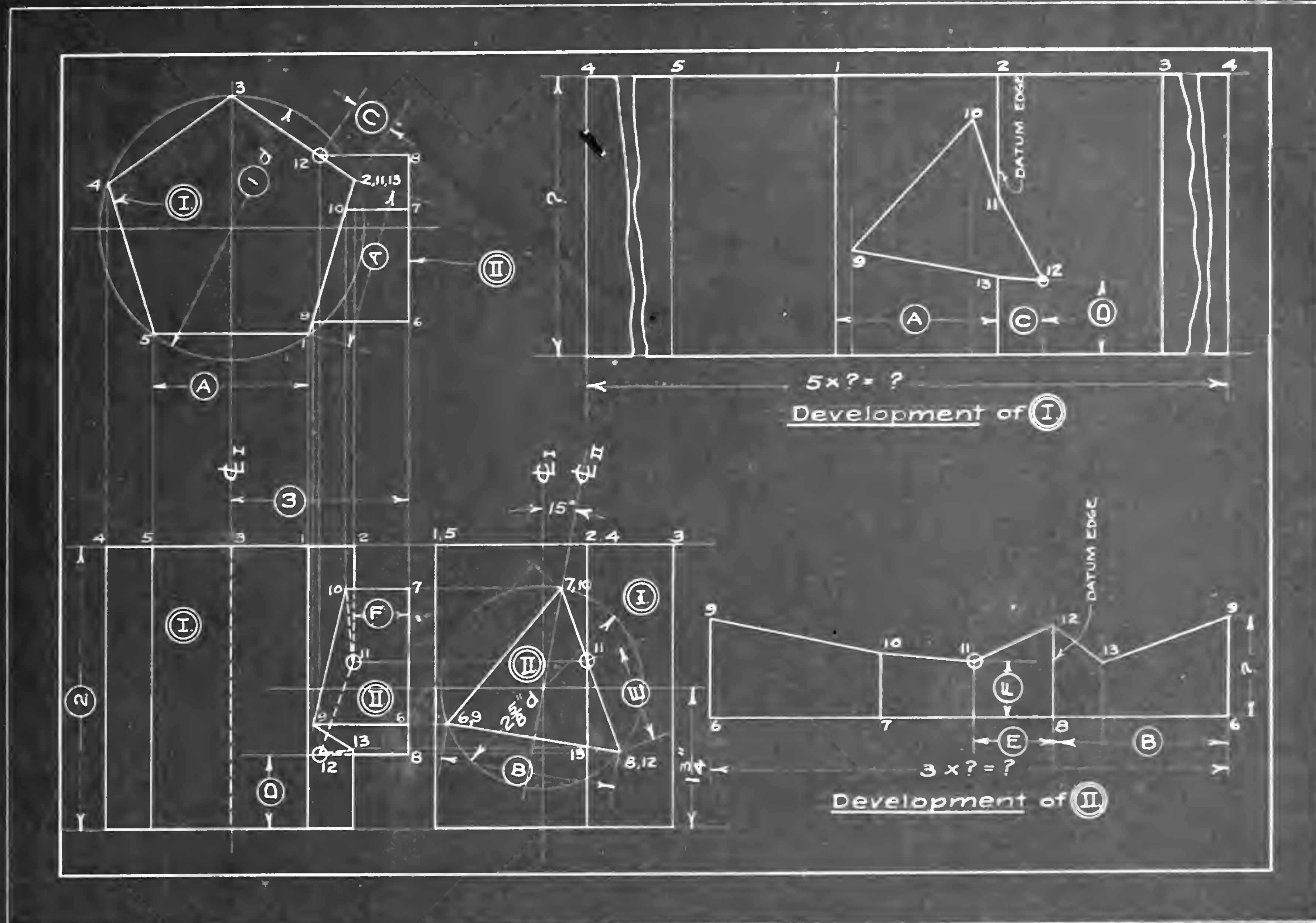
(*b*) Such an intersection is located first in a view where the plane is seen "edgewise" as a line. (See note at bottom of Page 60.)

(*c*) In **T.V.** an edge of the Triangular Prism starts from **7** and is intercepted at **10** by a plane of the Pentagonal Prism.

(*d*) Now the **F.V.** of this edge must be the same length, *i.e.* **7–10.** We can, therefore, locate point **10** in **F.V.**

(*e*) Similarly for other points of *Intersection*.

B. As on Plate *13* the purpose of Development is to obtain *Patterns* which, when cut and properly folded, will produce the original subject drawn.



DATUM EDGE
5 × ? = ?
Development of I
15°
$2\frac{5}{8}$" d
DATUM EDGE
3 × ? = ?
Development of II

Plate 17

LECTURE DATE..........

DIRECTIONS

I. (*a*) Block out 3 views of Large Cylinder (**I**).

Use identifying numbers and letters on all points as suggested.

(*b*) Block out **F. V.** and **E. V.** of Small Cylinder (**II**).

(*c*) Work out **T. V.** and **R. V.** of (**II**).

In stepping off arcs use *very small* intervals. (See PAGE 29—FIG. 2.)

(*d*) Work out **F. V.** and **R. V.** of Intersection.

(*e*) Draw Developments.

In Development of II cut cylinder at some other place than that shown on blue print.

II. Dimensions "?" are to be supplied by scaling the drawing.

Questions for Consideration

(1) If two cylinders of equal diameter (axes crossing at angle of 90°) intersect, what do **F. V.** and **R. V.** of intersection become?

(2) Given cylinder (II) as shown, but a square *prism* instead of cylinder (I). What are the 3 views of the curve of intersection?

NOTES

A. Method of Construction.

(*a*) A *vertical* Auxiliary Plane parallel to axis of the small cylinder (as shown by its trace, **12–m–h, R. V.**) will cut a line (**12–z**) on the surface of the small cylinder.

(*b*) In the different views this line **12–z** is identified thus:

In **T. V.** and **R. V.** by distance **A.**
In **F. V.** by projecting point **12** from **E. V.** or **R. V.**
In *all* views **12–z** is parallel to axis of small cylinder.

(*c*) Having identified the views of this line or *Element* (see Note A–a on PAGE 60) of the cylinder, we proceed with the construction precisely as if the element were the edge of a prism, following the method of PLATE 17.

In **T. V.** the element is intercepted at **m** by surface of Large Cylinder; by projecting down, therefore, we identify point **m** in **F. V.** This gives one point in the curve of intersection. The others can be found similarly, and curve drawn.

The Auxiliary Plane would also cut surface of small cylinder on *under side*. Each plane, therefore, will give two points of intersection.

B. Auxiliary Planes can be taken at will, but for convenience in development it is best to make arcs **1–2**, **2–3**, etc., on **E. V.** all *equal*.

In laying out Development of **II** take length of circumference and divide into proper number of parts.

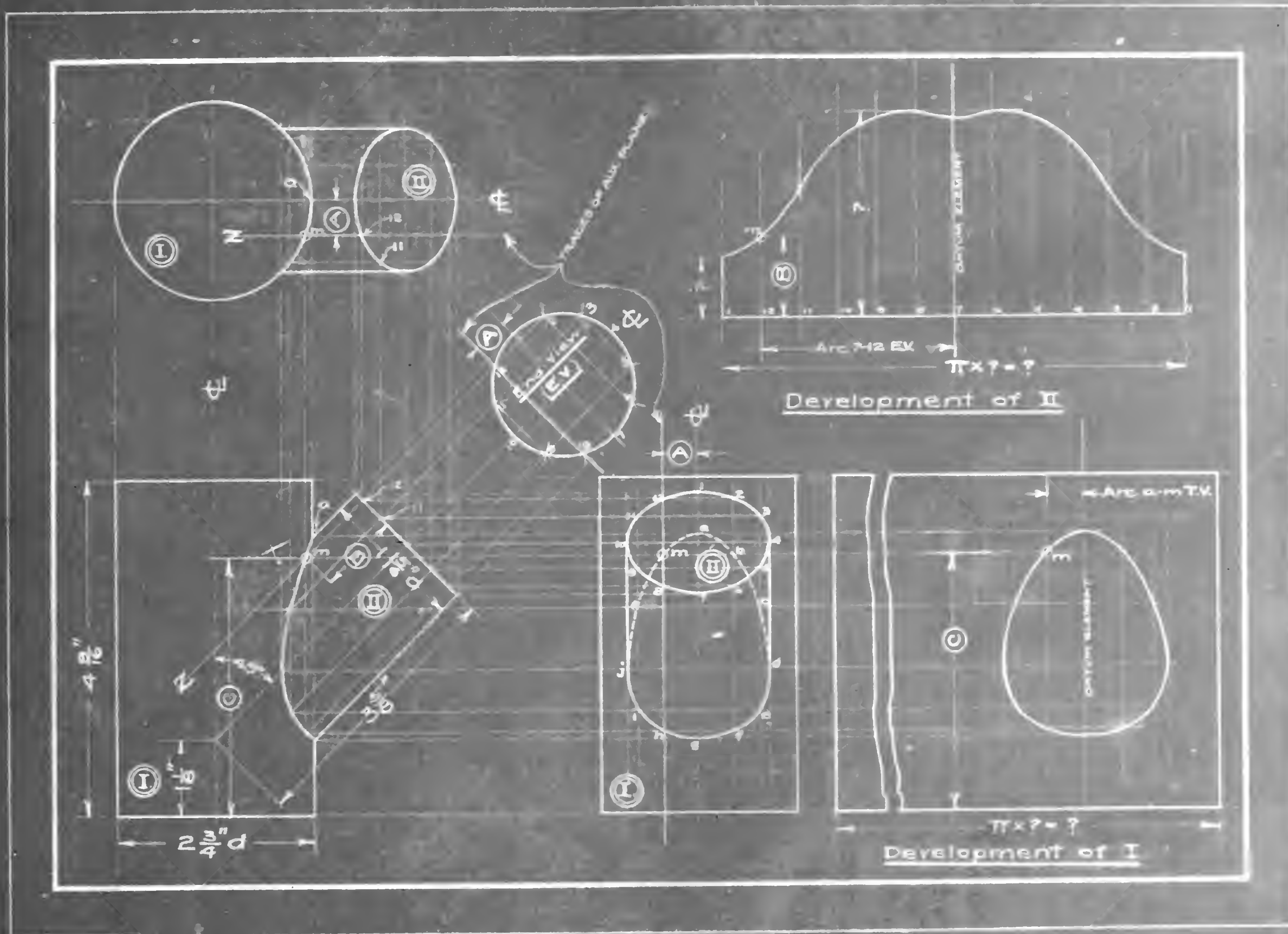

Traces of Aux. Planes
End View
E.V.
Arc 7-12 E.V.
π x ? = ?
Development of II
Arc a-m T.V.
π x ? = ?
Development of I
2 3/4" d
1 5/8" d
4 9/16"

Plate 18

LECTURE DATE..

DIRECTIONS

I. Draw first the *Orthographic Views.*

II. Develop the *Isometric Drawing* from the Orthographic Views. Start with Point **1**, and build up the figure by locating *successive points* (method indicated by reference distances) and then join the points by the required straight or curved lines.

When small curves cannot be conveniently drawn with the French Curve, a radius can often be found to approximate the required curve, and compasses can be used.

Questions for Consideration

(1) What lines, if any, appear in the Isometric Drawing *longer* than their real length?

(2) If so, how do you explain the fact?

NOTES

A. **Isometric Drawing*** is a method of showing, in one View, what in *Orthographic Projection* requires two or more views. It resembles a distorted *Perspective Drawing.*

B. Briefly, in Orthographic Projection we have 3 axes which can be called *Width* (**W**), *Depth* (**D**), and *Height* (**H**), respectively.

In Isometric Drawing these are all combined in one View by imagining an object tipped at an angle. This tipping is such as to make the **W** and **D** axes each form an angle of **30°** with the *horizontal*, while the **H** axis remains *vertical.*

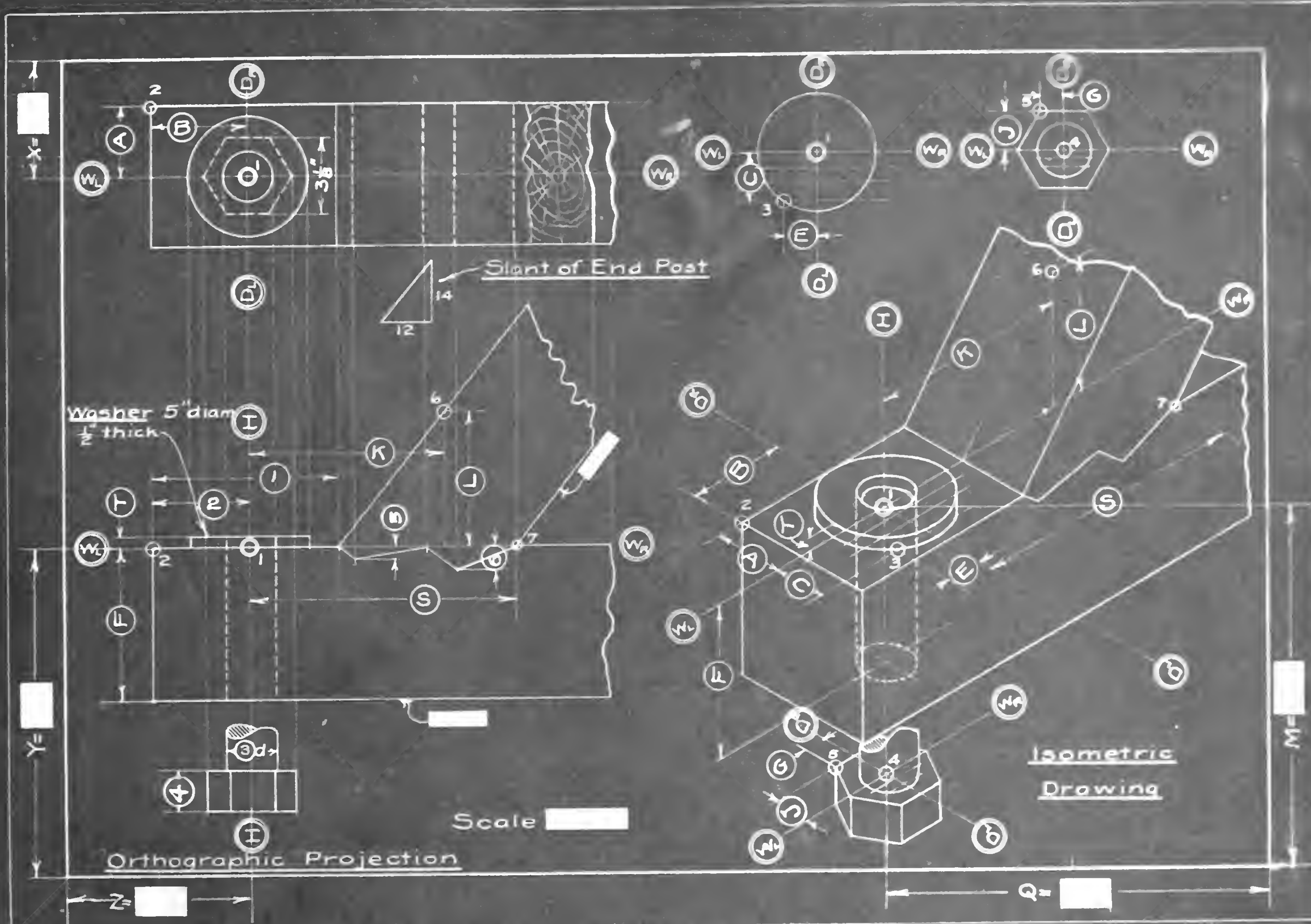
Any distance parallel to any one of the 3 axes in Orthographic Projection is then laid off in the Isometric Drawing in its *true length* parallel to the corresponding axis.

By joining points thus located we develop an Isometric View.

C. It follows from above that *only those lines which are parallel to any one of the 3 axes* are shown in their *true length* in an Isometric Drawing.

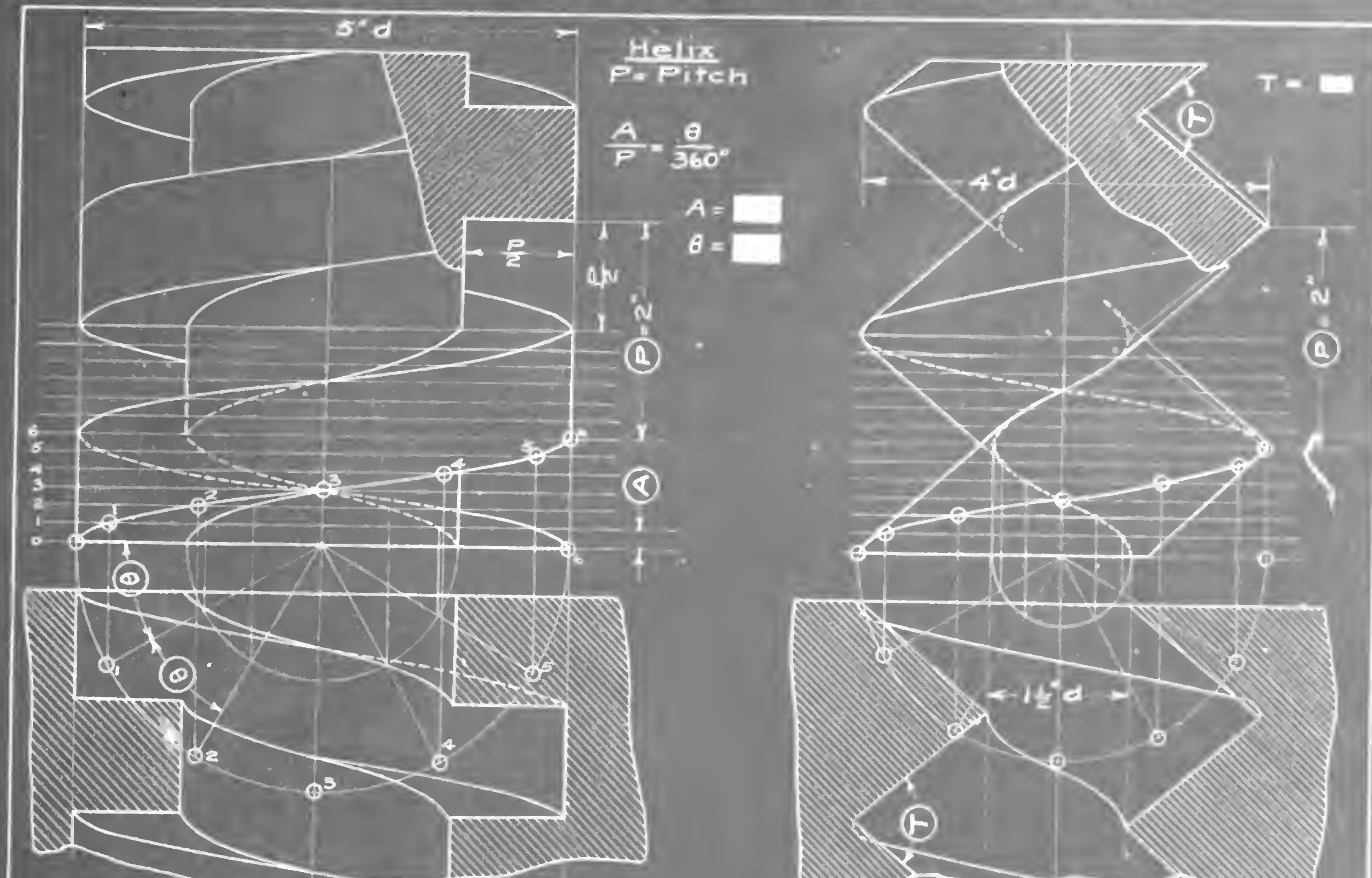
D. The subject of this sheet is the "End Post" joint of a timber Roof or Bridge Truss.

* A distinction must be noted between the above described Isometric "*Drawing*" and strict Isometric "*Projection.*" In the latter the lengths of all lines parallel to any one of the axes would be 0.8165 times their true length. In practice, however, this correction is rarely made, and the true lengths instead of the corrected ones are used as above described.



Note: Timber sizes are stated thus: 2×4 (2"×4"), 6×6, 6×8 etc.

ON YOUR SHEET SHOW SECTION ON LEFT SIDE OF ℄ INSTEAD OF RIGHT.



I. Square Thread and Nut

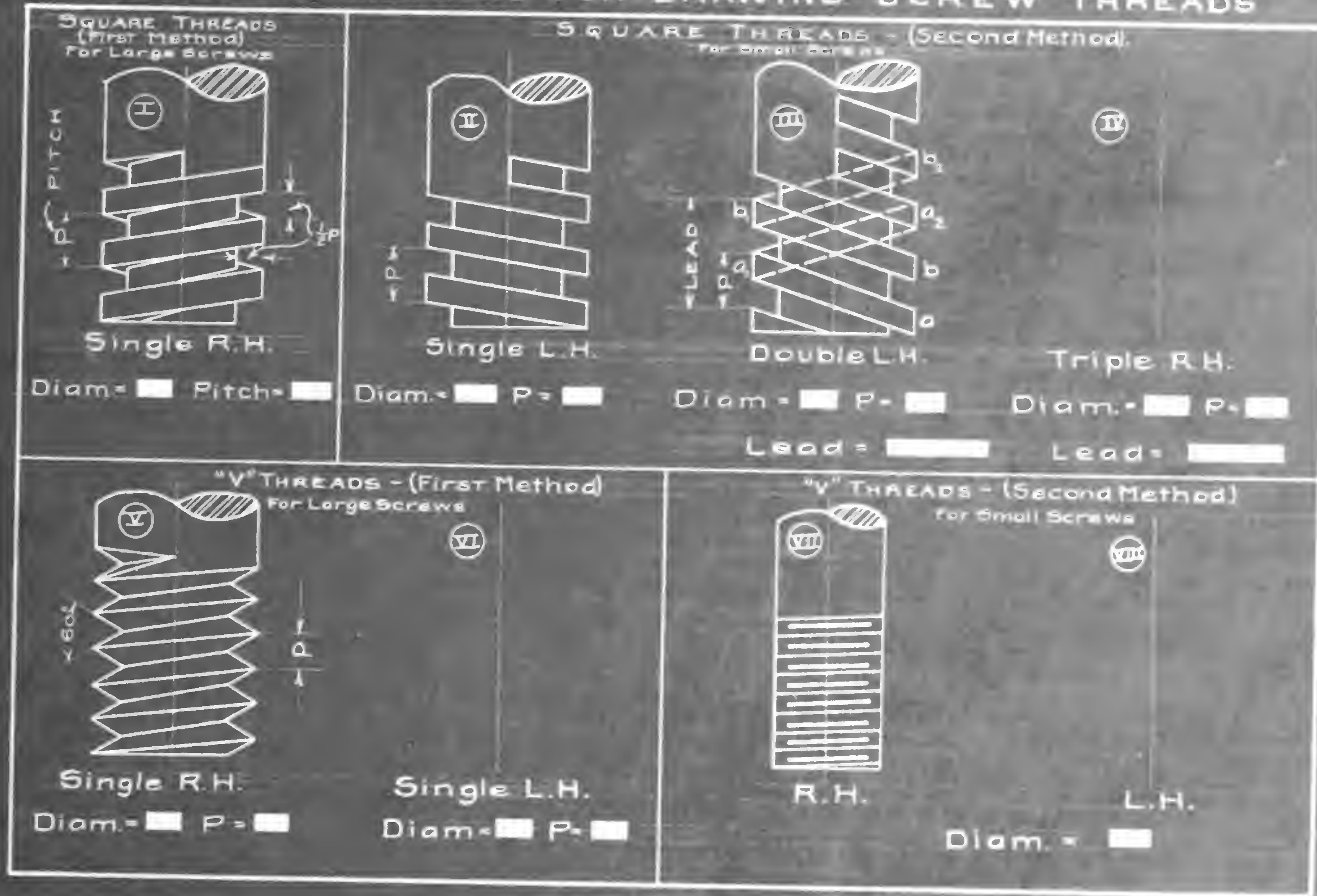
II. "V" Thread and Nut

I. (1) θ = some convenient divisor of 360° - make it to give at least 8 points in semi-circumference.
(2) Make A to correspond (3) Record values of A and θ selected.

II. (1) T = "angle of thread" In this case scale off T with protractor and record above.
(2) For standard threads T usually equals 60° [See page 113]

Plate 20

CONVENTIONAL METHODS FOR DRAWING SCREW THREADS

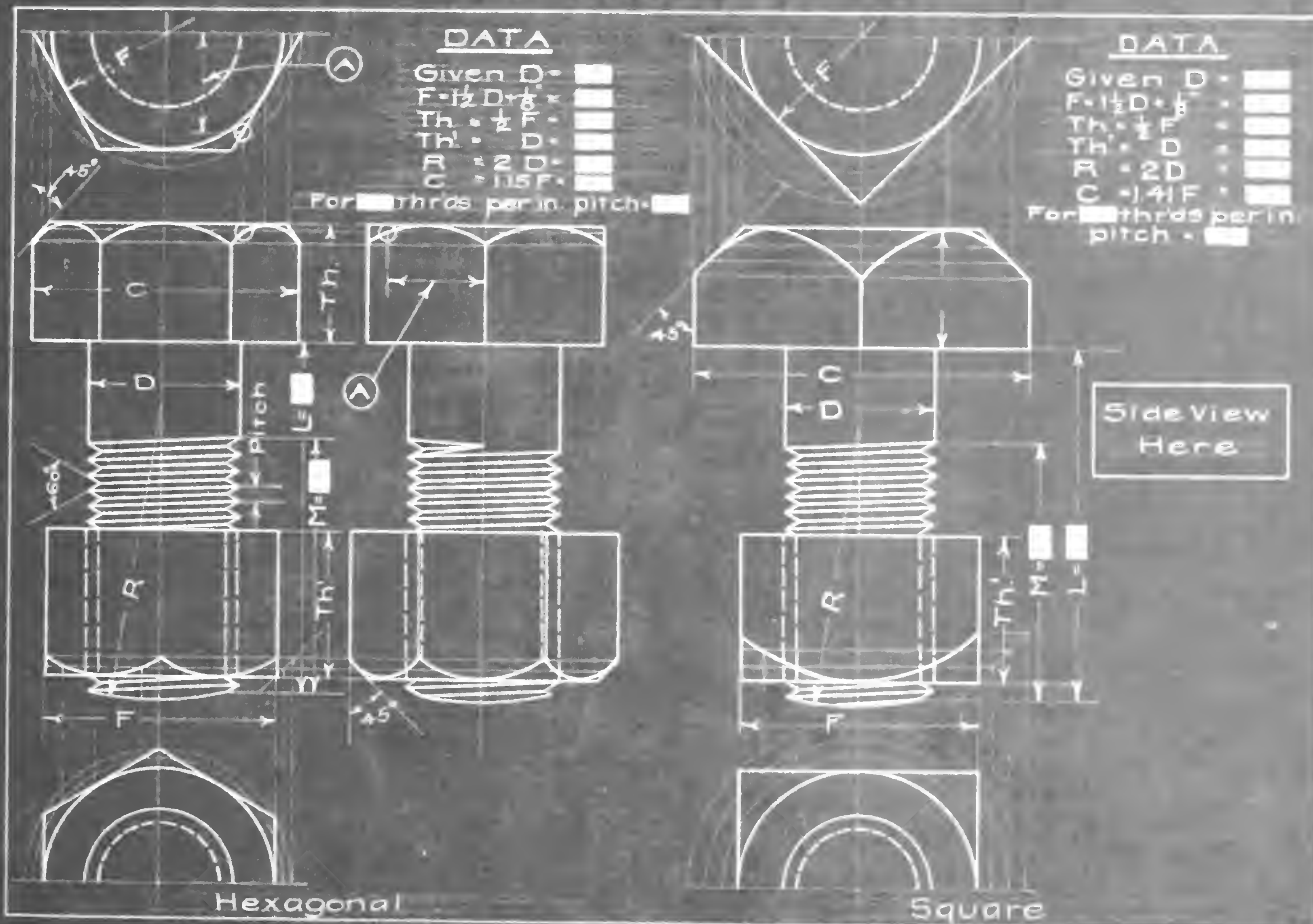


Note: (a) R.H. = Right Hand, L.H. = Left Hand.

(b) "First Method" (for both "Square and V") given above is slightly conventionalized and may be used on Large Threads (Compare Plate 20).
"Second Method" is freer convention used on Small Threads.

(c) In III notice that a, a_1, a_2 is one distinct thread and b, b_1, b_2 another quite independent of the first.

(d) "Lead" = 2P for double thread, = 3P for triple, etc.



PROPORTIONS FOR STANDARD BOLT AND NUT

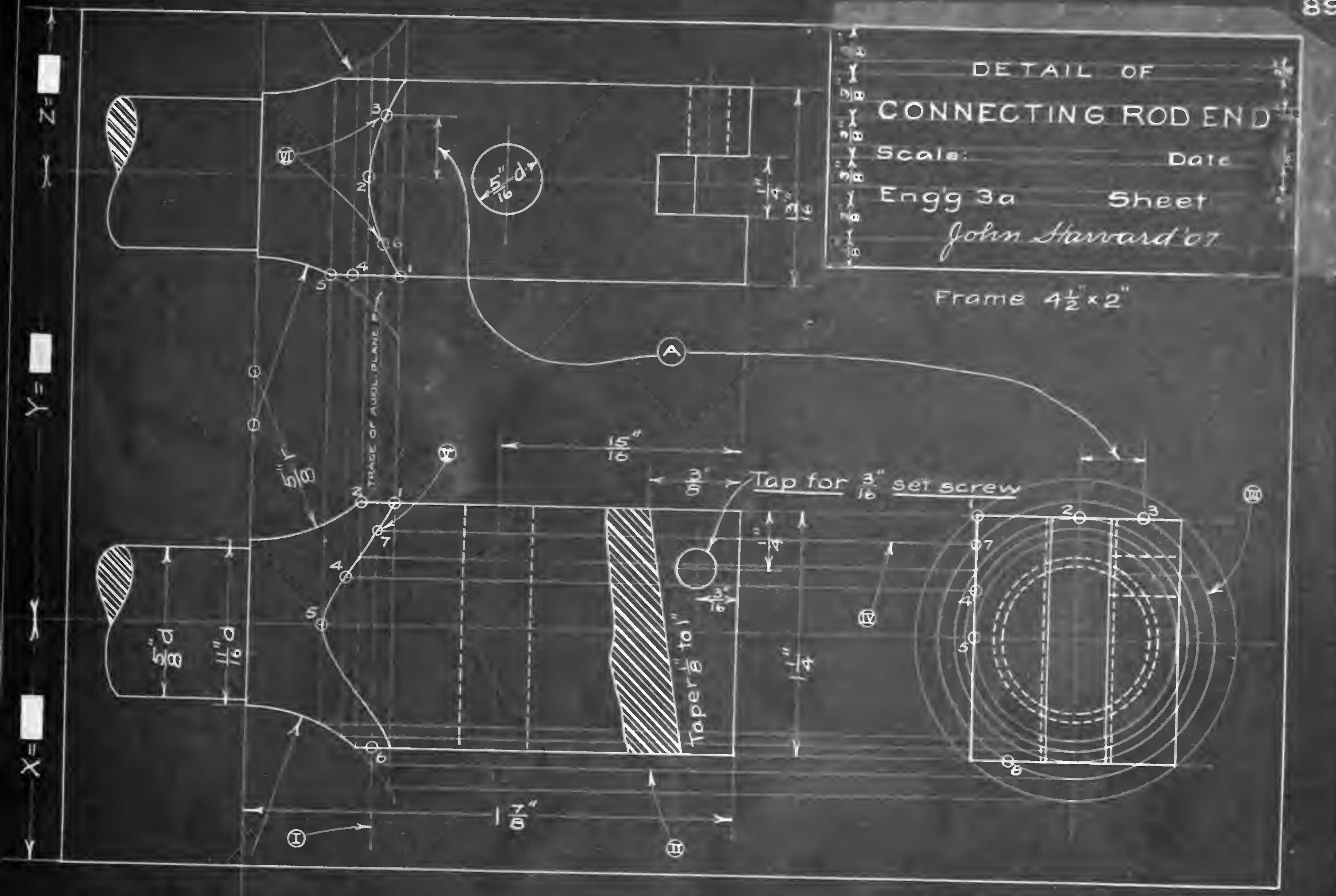
Note (a) This plate shows proportions as the bolt and nut are made in the shop according to a common standard.

(b) A conventional method of drawing the hexagonal bolt and nut is given on PAGE 113-VI

(c) For no. of threads per inch - standard for diam. - see PAGE 113-I

(d) To define a standard bolt, only 3 dimen. are needed
Diam. (D), Length (L), Distance Threaded (M)

Plate 22



(1) Use Auxiliary planes perpendicular to axis of rod. (Plane P for example)

(2) I, II, III, etc. show order of construction for plane P

Plate 23

III shows liberty taken with section view of spoke

IV shows different ways to draw sections

V shows all necessary dimensions in one view

I

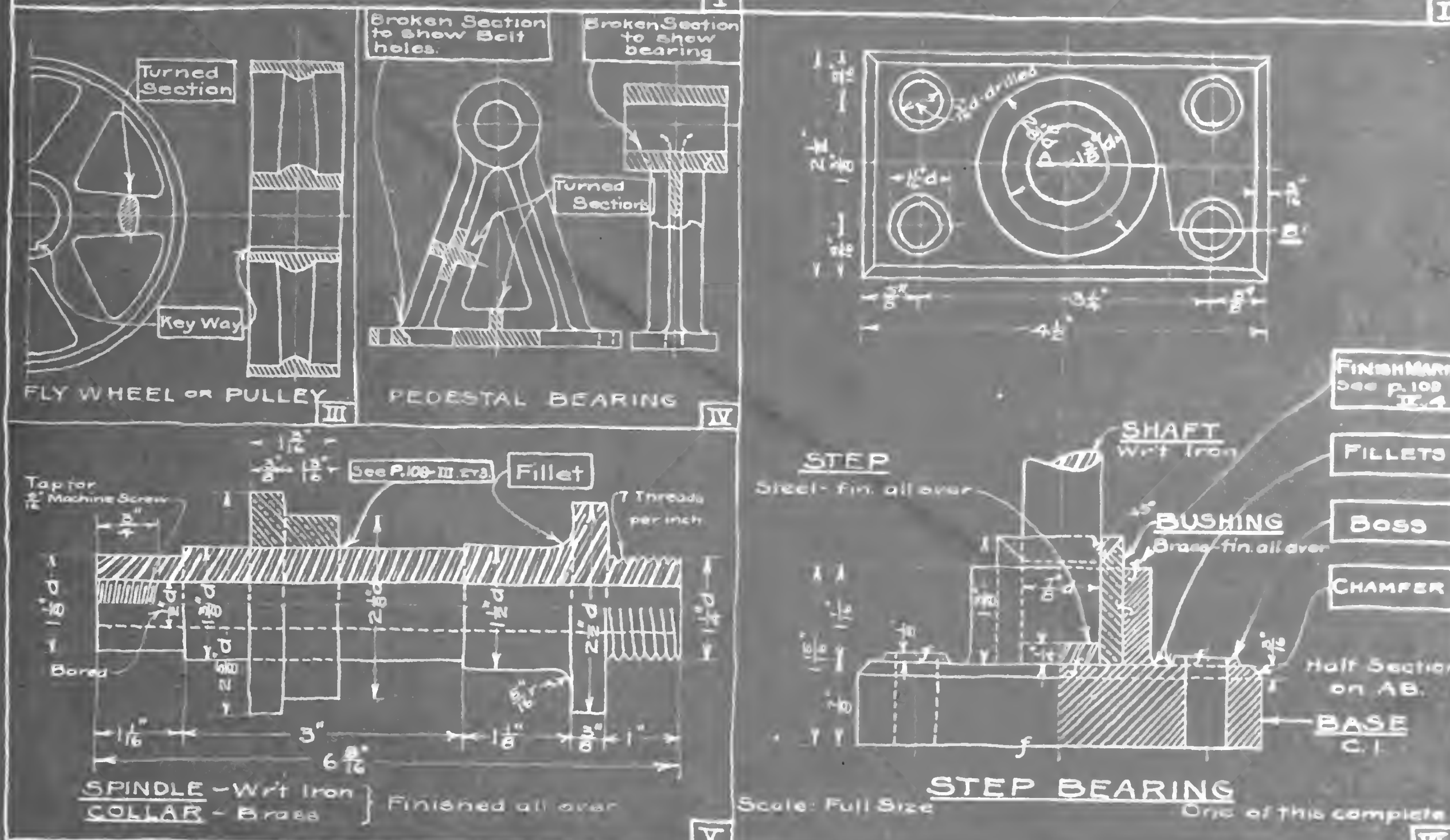
VI shows (a) several parts drawn together

(b) section on given line with shaft unsectioned

(c) drilled holes - size and location

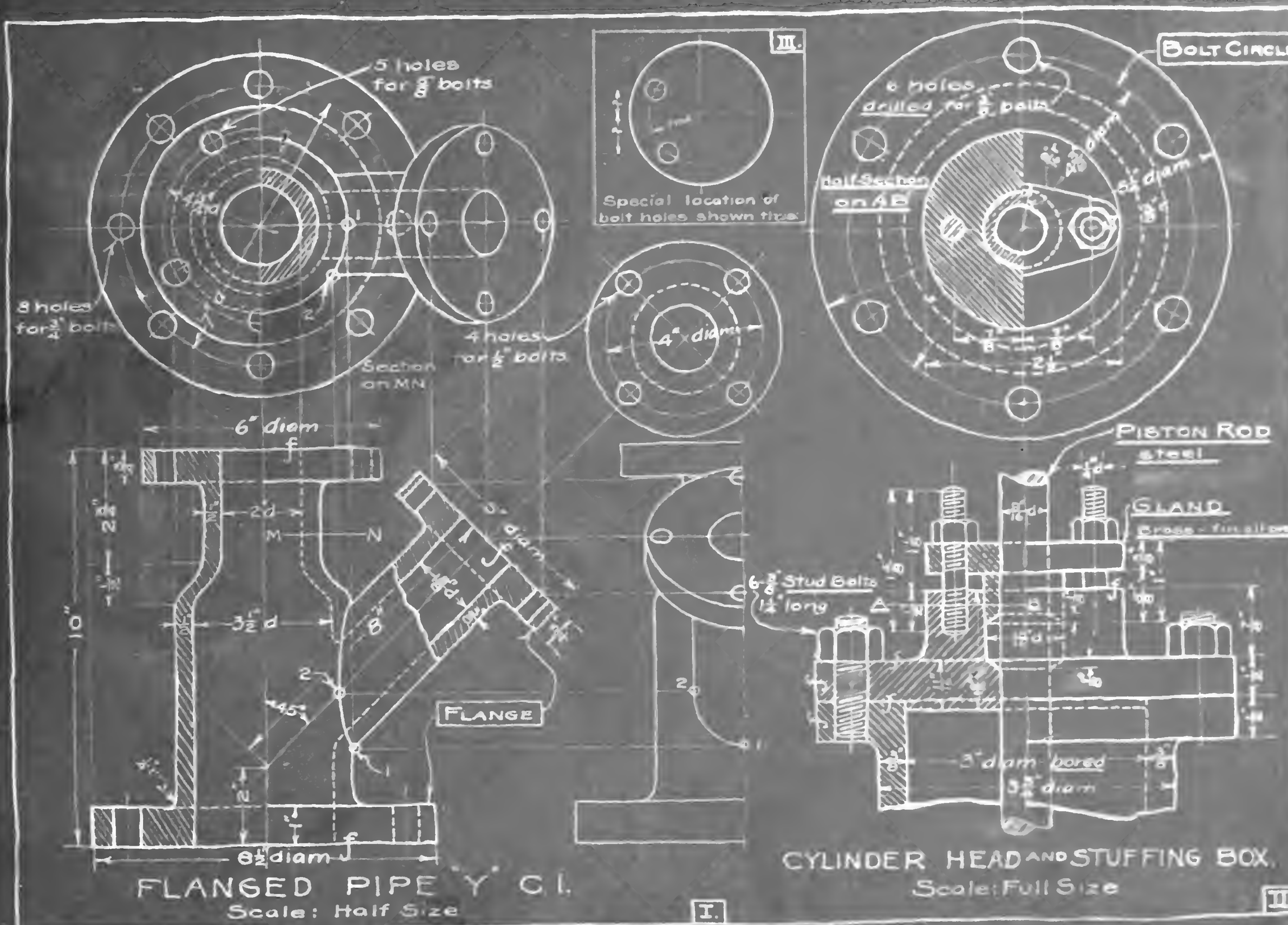
(d) surfaces to be machined by "f"

II



SOME DRAFTING CONVENTIONS

Plate 24



NOTE: This sheet shows.

(1) Method of defining Bolt Holes (I & II)

(2) Liberty taken with Projection of Bolt Holes (I & II)

(3) Method of "HALF SECTION" with Rod and Bolts in place (II).

Plate 25

SUBJECT—ENGINE CRANK

LECTURE DATE..

PLATE 26 — PREPARATION OF A WORKING DRAWING

SUBJECT — ENGINE CRANK

DIRECTIONS

I. **Freehand Sketch.**

(*a*) Crank is to be drawn carefully FREEHAND on Sketching Pad.

(*b*) Draw directly from the object, obtaining proportions BY EYE ALONE.

(*c*) Follow stages.

1. *Block out.* (See notes **A** and **B**.)
2. Complete outlines, ready for dimensions. (Then correct your drawing by comparing with large blue print in drawing room.)
3. Draw *dimension lines.* (Follow III on PAGE 97.)
   - (*a*) Dimension figures. (Measuring crank with rule and calipers.)
   - (*b*) Bill of Material. (See II on PAGE 97.)
   - (*c*) Title and other lettering.

     Same arrangement of title as given on PLATE 23 should be used.

II. **Pencil Drawing.**

(*a*) To be done with instruments on Duplex paper.

(*b*) Correct carefully but do not put check marks on this sheet. Sheets will be exchanged and checked later when notice is given.

III. **Tracing.**

NOTES

A. Choose your own set of views without consulting those given on PAGE 97. After choosing and blocking out views, submit to an instructor for discussion of merits of the choice.

B. **Choice and arrangement of views.**

1. Select for **Front View** one which gives clearest idea of object.
2. If possible place **F. V.** to show object in its *natural position*.
3. Draw as many other views as are necessary to show the object clearly.
4. Select views which show important lines *full* rather than *dotted*.

   NOTE. — Hidden lines (dotted) should be drawn only when they add to the general clearness of the drawing.
5. **Arrange all views** in accordance with the principles of Projection given on earlier sheets (*i. e.* **T. V.** above; **B. V.** below; **R. V.** at right; etc.). This is the usual practice in the United States.
6. To avoid confusion, hold object stationary and imagine your own standpoint changed for each view, instead of turning the object itself.

C. The **Bill of Material** (PAGE 97–II) is a list of all the parts with certain information about each one. The witness marks (first column), though not always shown, help to identify parts, especially when there are several on the sheet, or when a part has no commonly used name.

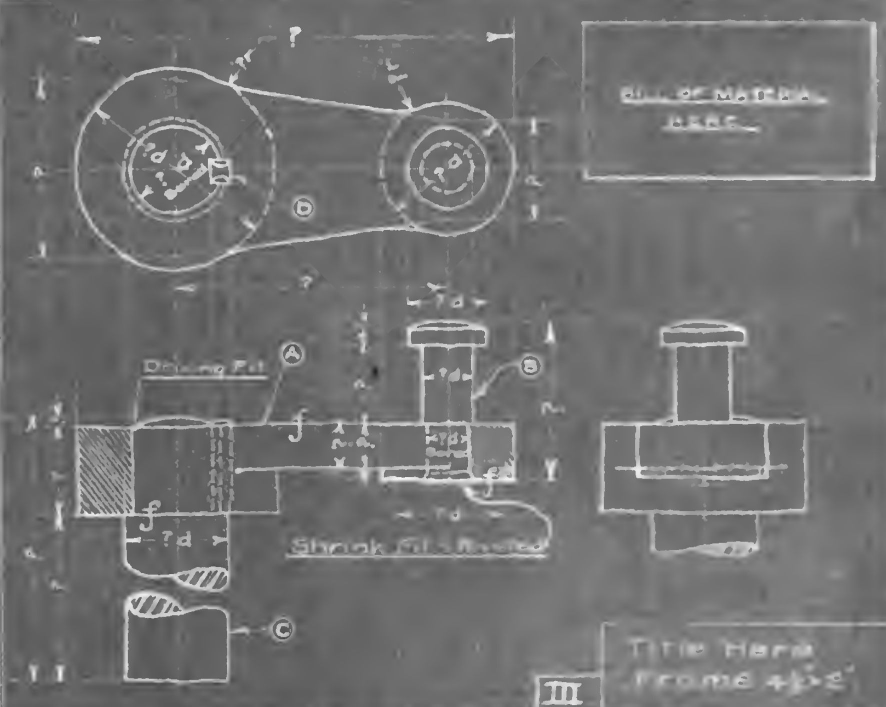
III is one of many possible arrangements - taken merely for illustration. It would perhaps be better to have axis of shaft horizontal in F.V. - its natural position on on engine.
IV shows 4 possible arrangements - all correct - 2 & 4 perhaps best - axis of shaft in natural position.
V shows 4 other arrangements, also correct but less satisfactory - too many important lines hidden.

I

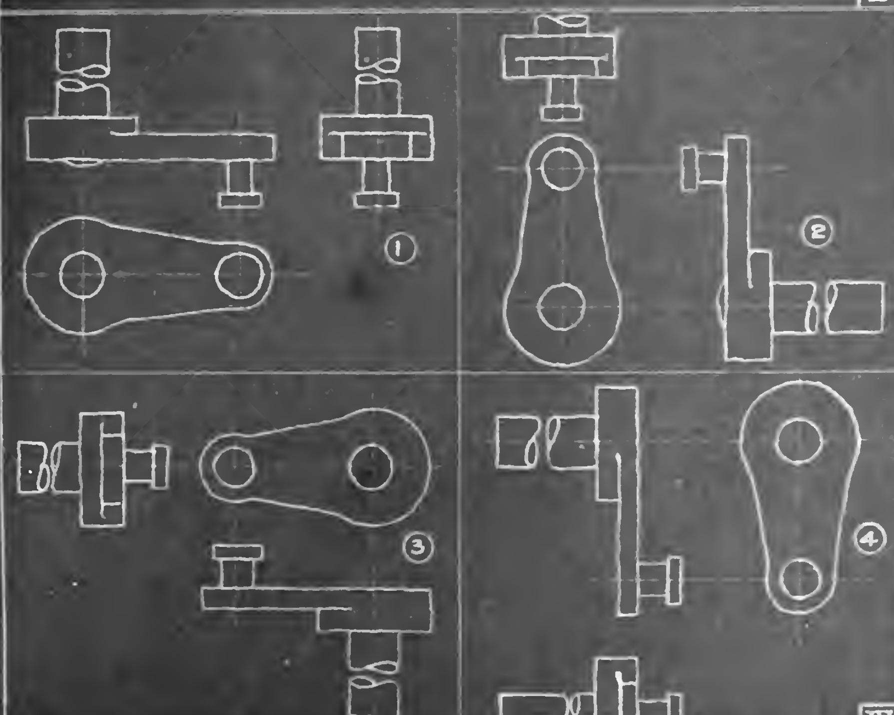
BILL OF MATERIAL

MARK	NO WANTED	NAME	MAT'L	REMARKS
A	1	Face	C. I.	
B	1	Pin	Steel	Finish all over
C	1	Shaft	W. I.	Finish all over
D	1	Key	Steel	$\frac{3}{8}'' \times \frac{3}{8}'' \times 1\frac{1}{4}''$

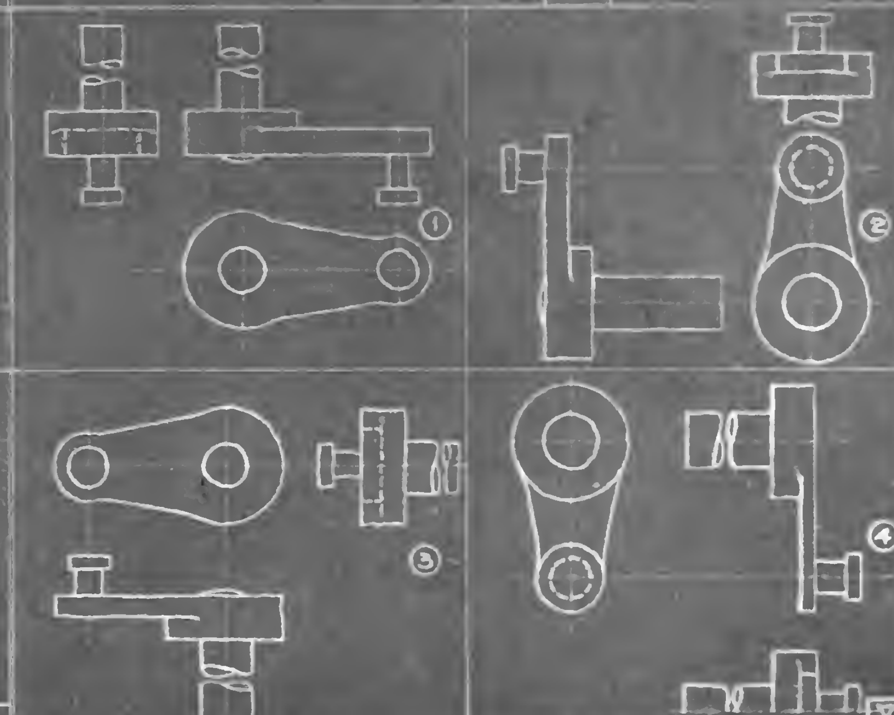
II



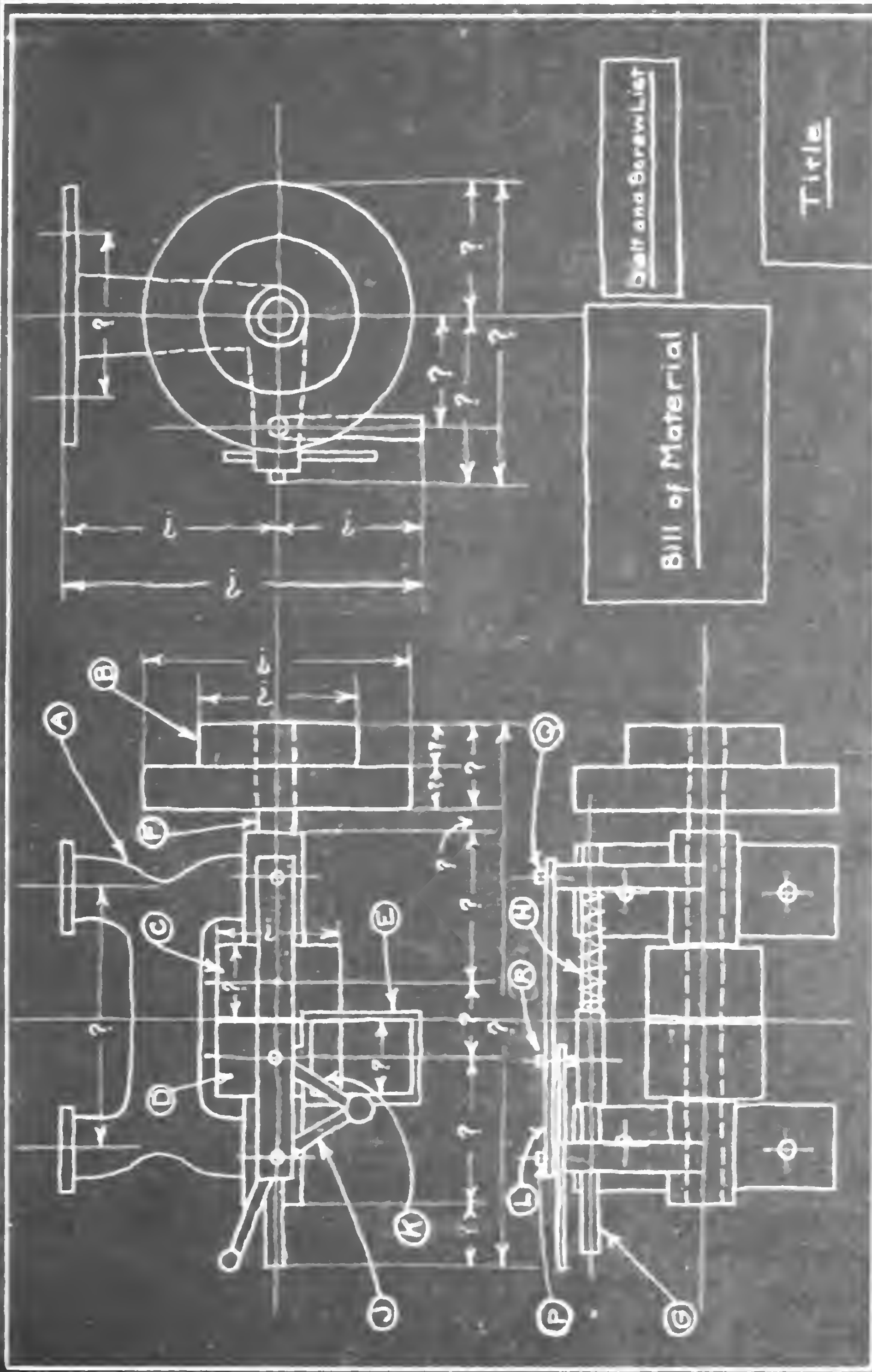
III



IV



V



BILL OF MATERIAL

MARK	NO WANTED	NAME	MAT'L	REMARKS
A	1	Frame	C.I.	
B	1	Cone Pulley	C.I.	with Set Screw M
C	1	Tight Pulley	C.I.	" " N
D	1	Loose Pulley	C.I.	with Oil Hole
E	1	Shifting Yoke	C.I.	
F	1	Shaft	Steel	Finished Bright
G	1	Shifter Rod	W.I.	
H	1	Spring	Brass	#13 Wire B+S
J	1	Bell Crank Lever	W.I.	J and K connected
K	1	Link	W.I.	by Rivet O
L	1	Guide Plate	W.I.	

In Spacing Lines See page 107-2

BOLT AND SCREW LIST

MARK	NO WANTED	DESCRIPTION	MAT'L	FOR
M	1	$\frac{3}{8}'' \times \frac{1}{2}''$ Set Screw	Steel	Cone Pulley
N	1	$\frac{3}{8}'' \times \frac{1}{2}''$ Set Screw	Steel	Tight Pulley
O	1	$\frac{1}{4}'' \times \frac{5}{8}''$ Rivet	W.I.	Link
P	1	$\frac{3}{8}'' \times 1\frac{1}{8}''$ Cap Screw	W.I.	Guide Plate
Q	1	$\frac{3}{8}'' \times \frac{1}{2}''$ Cap Screw	W.I.	Guide Plate
R	1	$\frac{3}{8}'' \times 1\frac{1}{16}''$ Bolt	W.I.	Yoke

ARRANGEMENT OF STANDARD TITLE

Frame $4\frac{1}{2}'' \times 2''$

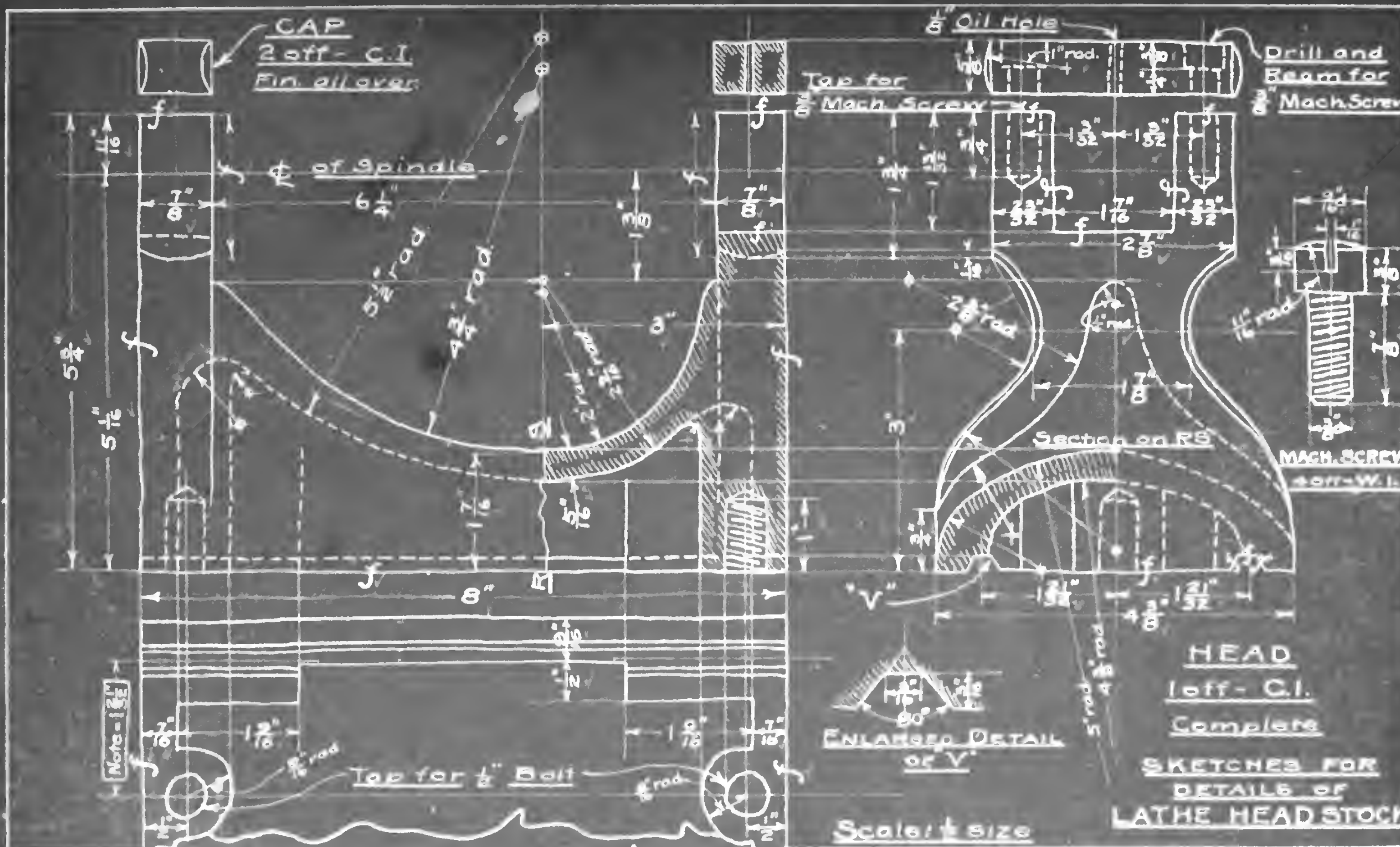
ASSEMBLY OF

COUNTER SHAFT

Scale: Half Size   Date

Engg 3a   Sheet

John Harvard '07


CAP
2 off - C.I.
Fin. all over
of Spindle
Tap for 1/8" Bolt
1/8" Oil Hole
Drill and Ream for 3/8" Mach. Screw
Tap for 3/8" Mach. Screw
Section on RS
MACH. SCREW
4 off - W.I.
ENLARGED DETAIL OF "V"
HEAD
1 off - C.I.
Complete
SKETCHES FOR DETAILS OF LATHE HEAD STOCK
Scale: 1/2 size

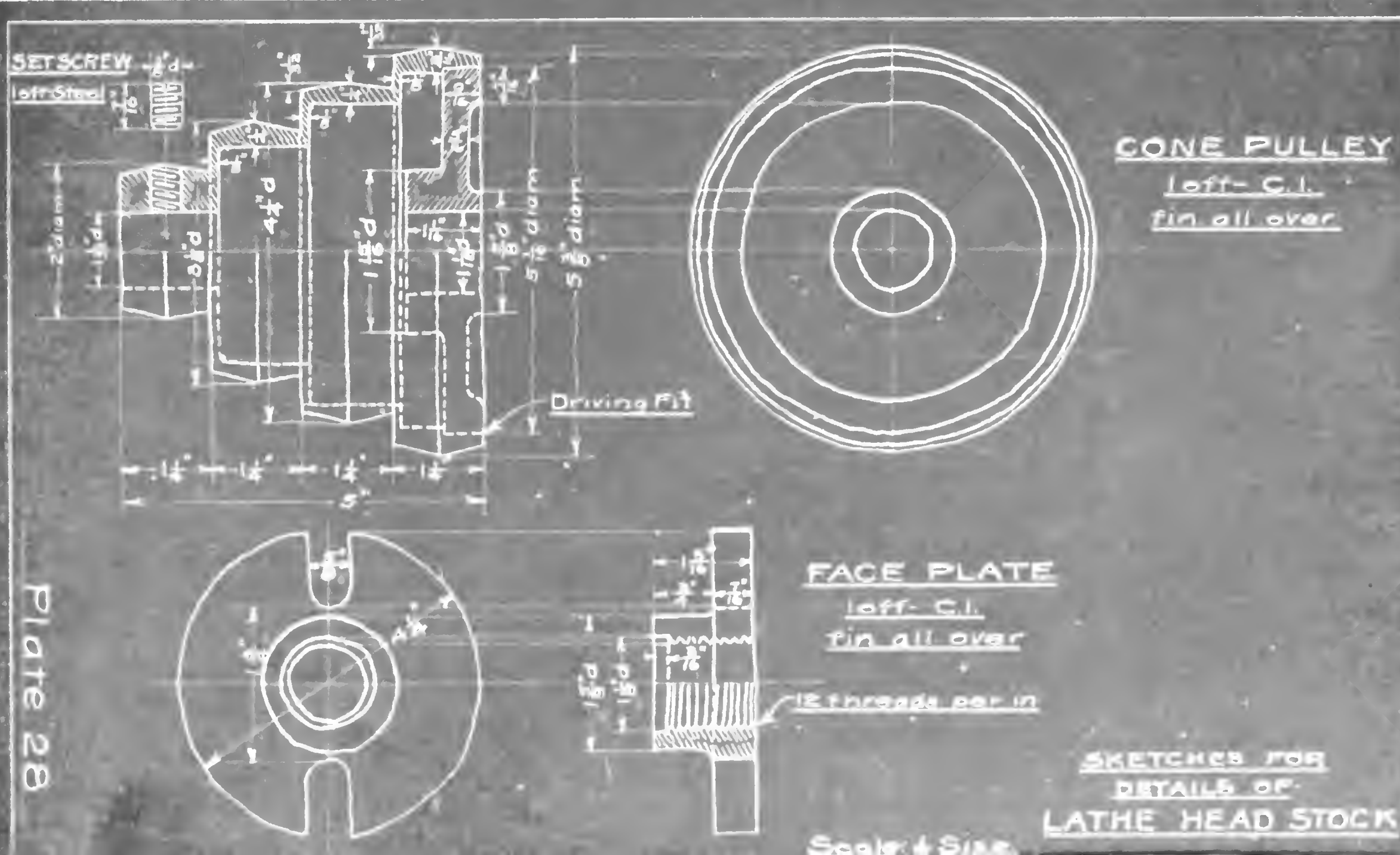
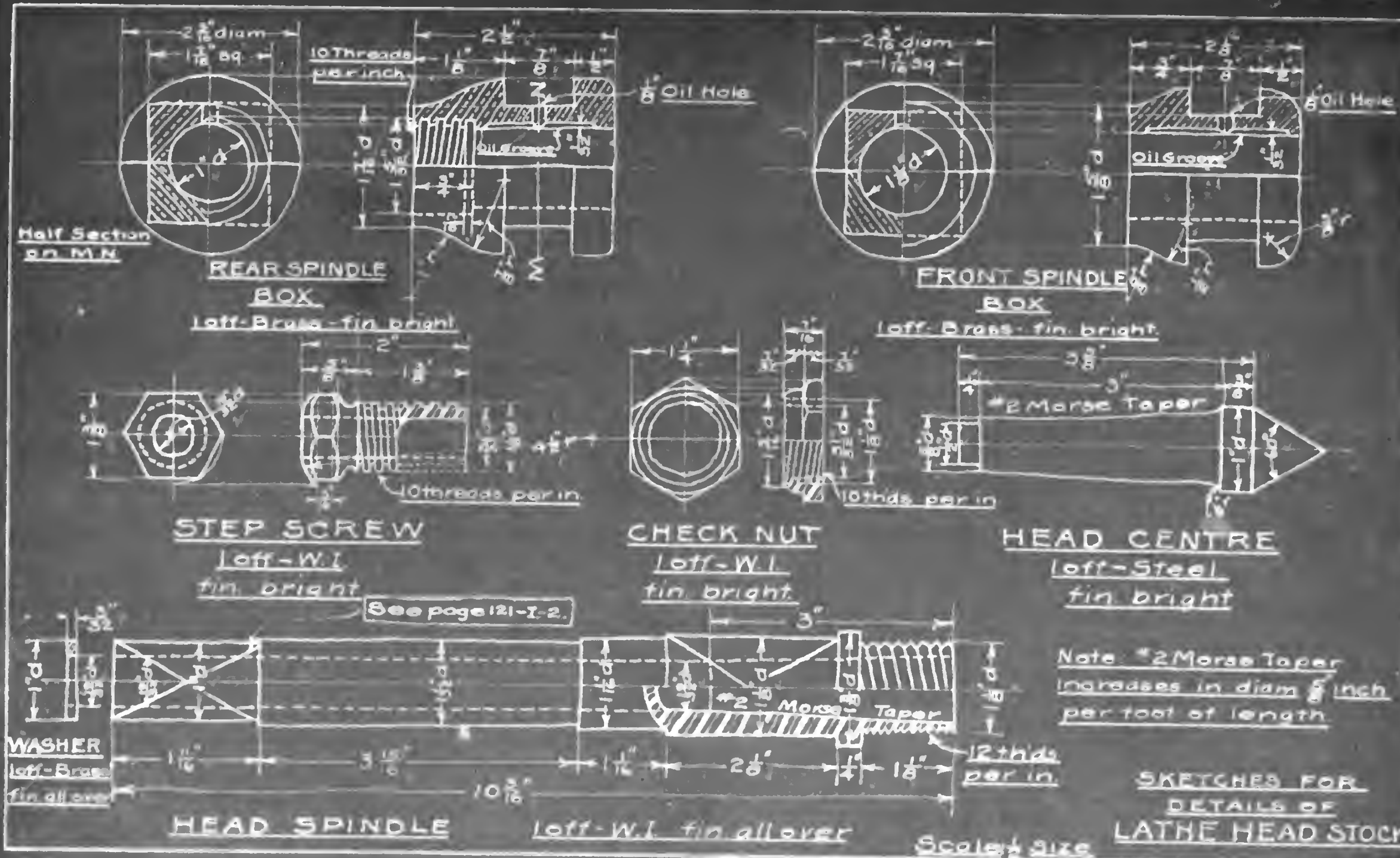

SET SCREW
1 off - Steel
Driving Fit
CONE PULLEY
1 off - C.I.
fin all over
FACE PLATE
1 off - C.I.
fin all over
12 threads per in
SKETCHES FOR DETAILS OF LATHE HEAD STOCK

Plate 28


REAR SPINDLE BOX
1 off - Brass - fin bright
Half Section on M.N.
10 Threads per inch
Oil Hole
Oil Groove
FRONT SPINDLE BOX
1 off - Brass - fin bright
STEP SCREW
1 off - W.I.
fin bright
10 threads per in
See page 121-I-2.
CHECK NUT
1 off - W.I.
fin bright
10 thds per in
HEAD CENTRE
1 off - Steel
fin bright
#2 Morse Taper
WASHER
1 off - Brass
fin all over
HEAD SPINDLE
1 off - W.I. fin all over
#2 Morse Taper
12 thds per in
Note #2 Morse Taper increases in diam 5/8 inch per foot of length
SKETCHES FOR DETAILS OF LATHE HEAD STOCK
Scale 1/2 size

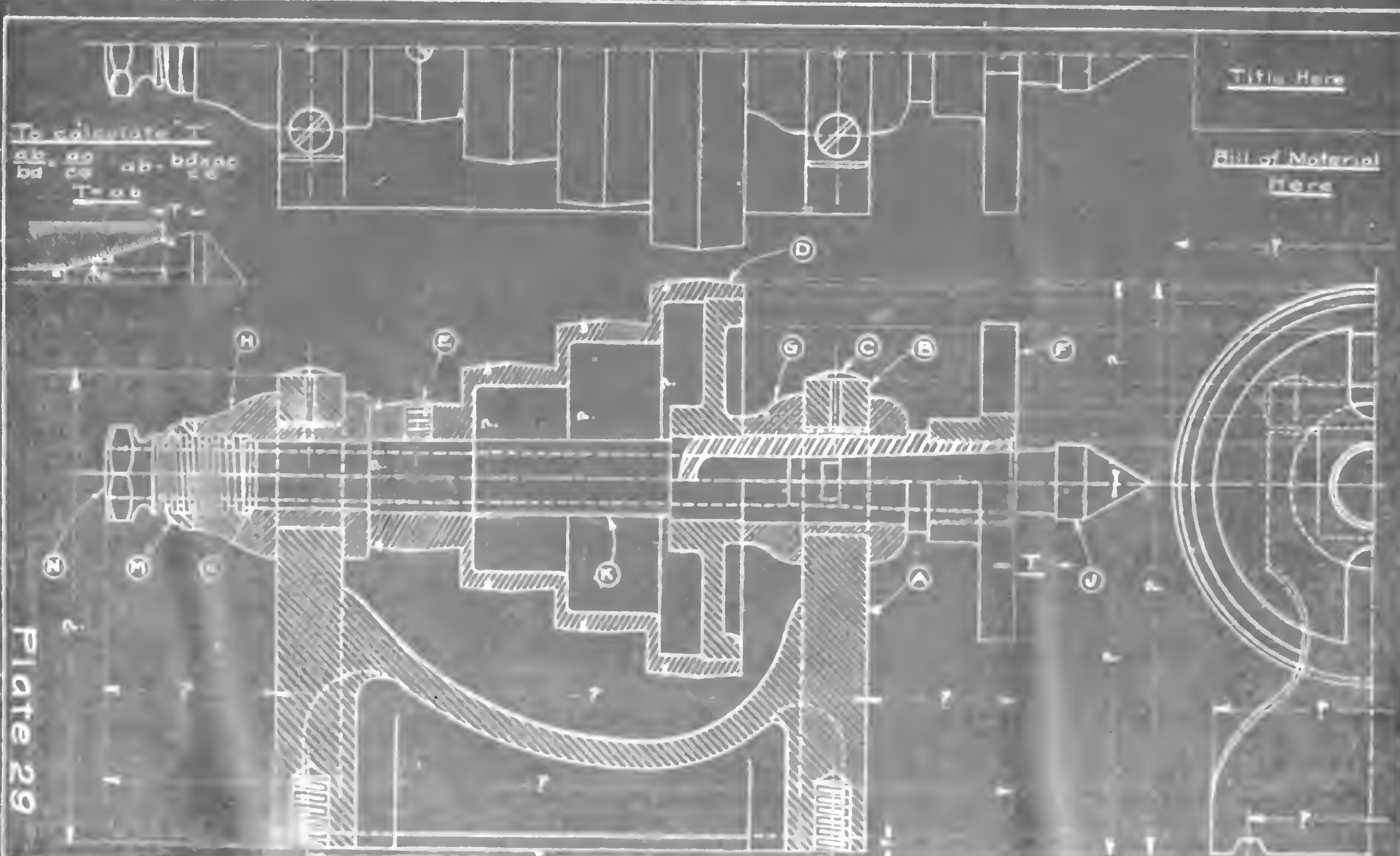

Title Here
Bill of Material Here
To calculate "T"
T = ab
A
B
C
D
E
F
G
H
J
K
M
N

Plate 29

VERTICAL SYSTEM

a b c d e f g h i j k l m

n o p q r s t u v w x y z

A B C D E F G H I J K L M

N O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 $\pi = 3.1416$

$\frac{1}{16}$ $\frac{3}{8}$ $\frac{1}{4}$ $\frac{5}{32}$ $4'-7\frac{9}{16}''$ $0''.3$ Sheet 12

About 30°

SLANTING SYSTEM

a b c d e f g h i j k l m

n o p q r s t u v w x y z

A B C D E F G H I J K L M

N O P Q R S T U V W X Y Z

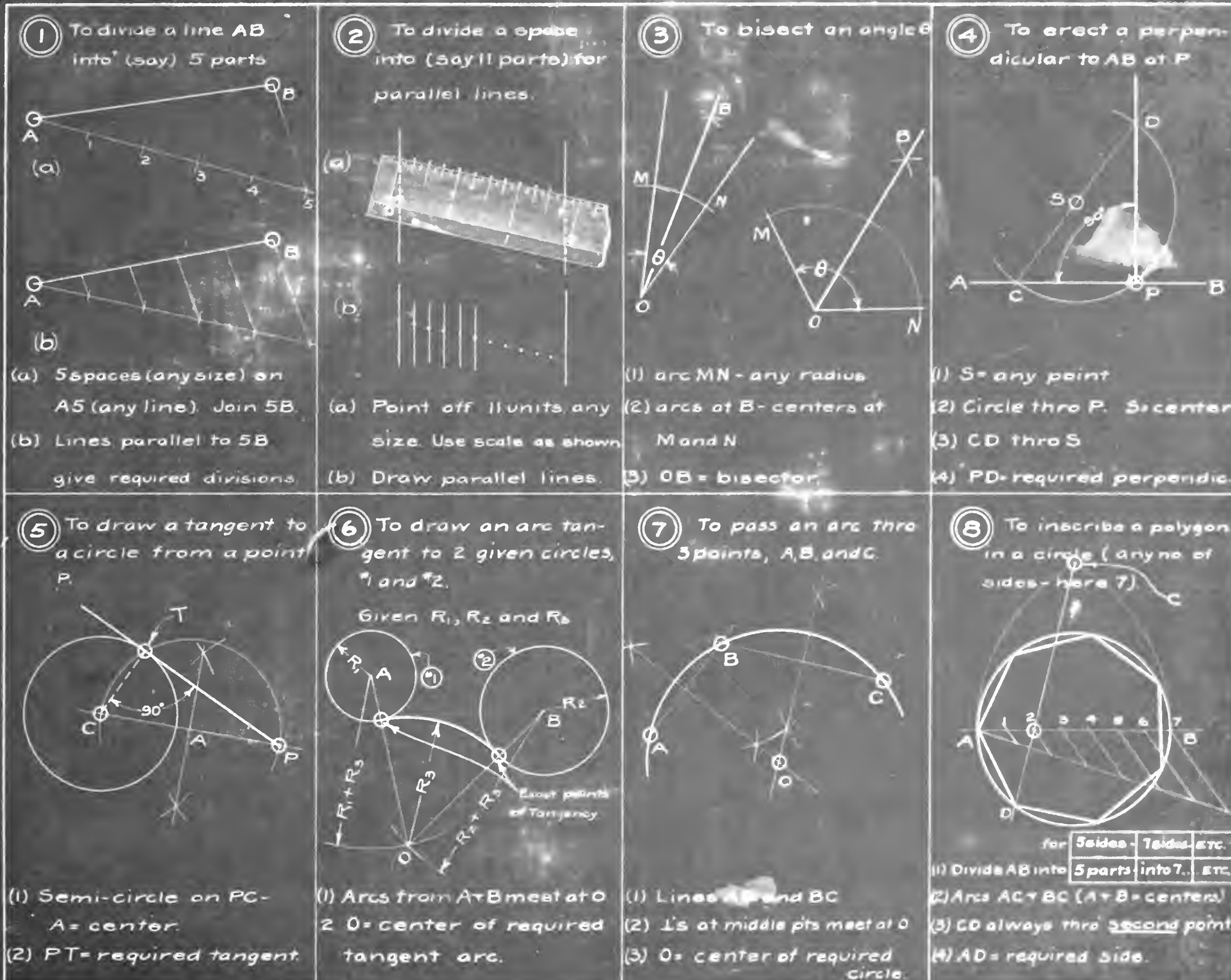
1 2 3 4 5 6 7 8 9 0 57.3°

$\frac{5}{8}$ $\frac{1}{2}$ $\frac{17}{64}$ $2\frac{15}{32}$ $37'-0\frac{7}{8}''$ $0''.05$ *Finish all over*

SUGGESTED METHOD FOR MAKING STROKES.

b n o s A J M U 2 5 8

N 8-30-06



1 To divide a line AB into (say) 5 parts
(a) 5 spaces (any size) on A5 (any line). Join 5B.
(b) Lines parallel to 5B give required divisions.
2 To divide a space into (say 11 parts) for parallel lines.
(a) Point off 11 units any size. Use scale as shown.
(b) Draw parallel lines.
3 To bisect an angle θ
(1) arc MN - any radius
(2) arcs at B - centers at M and N
(3) OB = bisector.
4 To erect a perpendicular to AB at P
(1) S = any point
(2) Circle thro P. S = center.
(3) CD thro S
(4) PD = required perpendic.
5 To draw a tangent to a circle from a point P.
(1) Semi-circle on PC - A = center.
(2) PT = required tangent.
6 To draw an arc tangent to 2 given circles, #1 and #2.
Given R1, R2 and R3
Exact points of Tangency
(1) Arcs from A + B meet at O
2 O = center of required tangent arc.
7 To pass an arc thro 3 points, A, B, and C.
(1) Lines AB and BC
(2) ⊥'s at middle pts meet at O
(3) O = center of required circle.
8 To inscribe a polygon in a circle (any no. of sides - here 7).
for 5 sides - 7 sides - ETC.
(1) Divide AB into 5 parts into 7 ETC.
(2) Arcs AC + BC (A + B = centers)
(3) CD always thro' second point.
(4) AD = required side.

Plate B

SHADING

(Usually in Inking only)

1. To give the effect of RELIEF to a drawing the Convention of Shading is often adopted.
2. The light is assumed to come in the direction of arrows - Fig. I.
3. All Bounding Lines which light does not strike directly are shaded.
   The shaded lines are simply inked somewhat heavier than the unshaded to give the effect of casting a shadow.
4. In general, Dotted Lines and Lines representing the intersection of two planes, both of which are visible, are not shaded.
5. SHADING CIRCULAR ARC (Fig. 2).
   Draw circle - centre A
   With SAME RADIUS and Centre at B (AB = abt 1/32") draw second arc from C to D. Similarly for small circle which represents a hole.

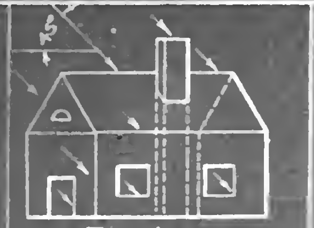


Fig. 1

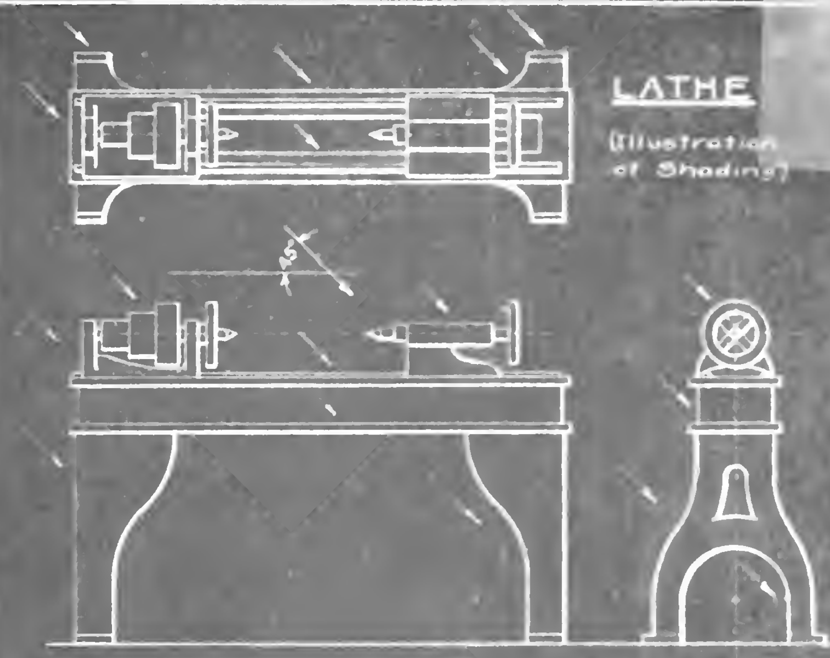
Note: All views of an object are shaded in same manner as above.

Fig. 2

I

LATHE

(Illustration of Shading)

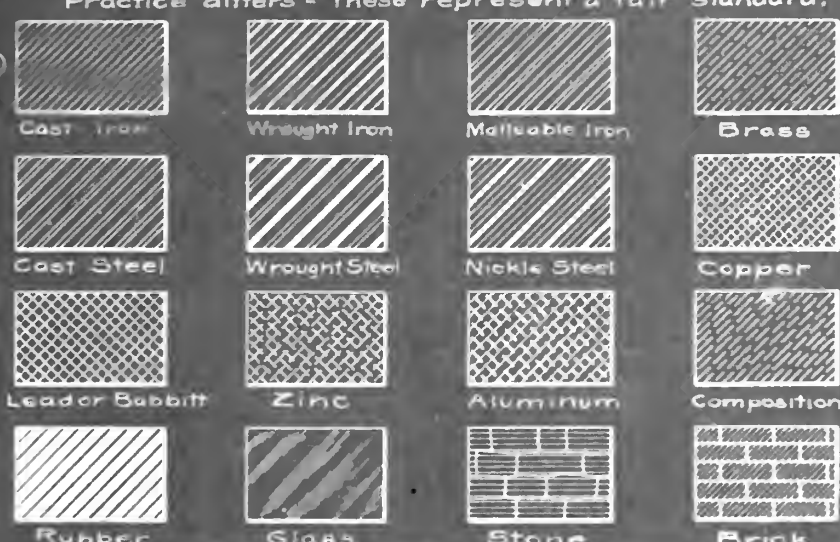


II

SOME CONVENTIONS FOR CROSS SECTIONS

Practice differs - these represent a fair standard.

①



② Usual angle for Crosshatching = 45°

③ Two or more separate pieces in contact, use hatching in different directions.

III

① TYPES OF LINES

(a) ——— Full (visible)

(b) - - - - Dotted (invisible)

(c) (d) — or — Centre Lines

Dimension and Extension Lines

② NUMBER OF PIECES WANTED

(a) "Two"

(b) "Two of this"

(c) "Make Two"

(d) "2 Off" or "Two Off"

(e) "2 Pieces" or "Two Pieces"

(f) "2 Wanted" or "Two Wanted"

③ WITNESS MARKS

(a) 12 Thrd per in.

(b) Ⓐ

(c) 7/8 drilled

(d) 5/8" Tap

④ FINISH MARKS

IV

SOME CONVENTIONS

Plate 32

IN GENERAL

(1) First dimension that view which shows details most clearly

(2) Avoid repeating dimensions on a second view.

(3) Dimension where possible to centre lines and finished surfaces

(4) Place dimensions outside of drawing if confusion would result from placing them inside.

(5) Dimension distances only in those views where they appear in their true length

SYMBOLS

(1) 9" = 9 inches 13" = 13 inches etc.

(2) 4' or 4'-0" = 4 feet 5'-6" = 5 feet - 6 inches

(3) Under 2 ft use inches; above 2 ft use feet and inches.

(4) 3" diam. or 3" d. = 3 inches diameter.

(5) 3" rad. or 3" r = 3 inches radius.

CONVENTIONS AND ILLUSTRATIONS

(1) Fractions thus: $\frac{3}{4}$" not thus: 3/4"

(2) Arrow Points thus: ← not thus: ← nor ←

(3) Extension Lines thus: not thus:

(4) Arrow Points always to touch lines dimensioned thus: not thus:

(5) Arrow Points always opposite thus: or not thus:

(6) Horizontal Dimensions thus: $2\frac{5}{16}$"

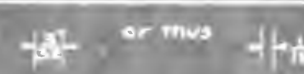
(7) Vertical Dimensions thus: not thus: nor

i.e. (Vertical Dimensions to read from RIGHT.)

CONVENTIONS AND ILLUSTRATIONS - CONT.

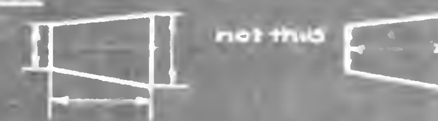
(8) Slanting Dimensions thus:

(9) Small Dimensions thus: or thus

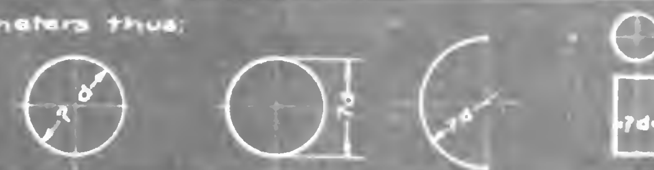


(10) Avoid using LINES OF DRAWING or CENTRE LINES as Dimension Lines.

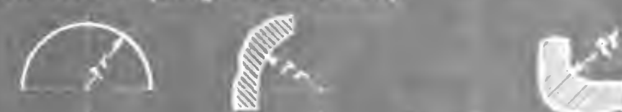
Correct thus: not thus



(11) Diameters thus:



(12) Radii thus: (only one arrow)

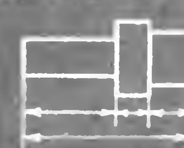


(13) Carry Dimensions where possible along one line.

thus: not thus:

(14) Give Dimension "Over All" as well as subdimensions

thus:



(15) Decimal Dimensions thus: 4.06" not 4.06"

CONCERNING DIMENSIONS

Plate C

U.S. STANDARD FOR "V" THREADS

Diam. of Screw	Threads per in.	Diam. at root of thd.	Diam. of Tap Drill
1/4"	20	.185	3/16"
5/16	18	.240	1/4
3/8	16	.295	5/16
7/16	14	.344	23/64
1/2	13	.400	13/32
9/16	12	.454	15/32
5/8	11	.507	17/32
3/4	10	.620	5/8
7/8	9	.731	3/4
1	8	.837	27/32
1 1/8	7	.940	31/32
1 1/4	7	1.065	1 3/32
1 3/8	6	1.160	1 3/16
1 1/2	6	1.284	1 9/32
1 5/8	5 1/2	1.389	1 13/32
1 3/4	5	1.491	1 1/2
1 7/8	5	1.616	1 5/8
2	4 1/2	1.712	1 3/4
2 1/4	4 1/2	1.962	1 31/32
2 1/2	4	2.176	2 3/16
2 3/4	4	2.426	2 7/16

I.

II.

STANDARD PIPE THREADS

Taper of threads = 1/16 on diam. per in.

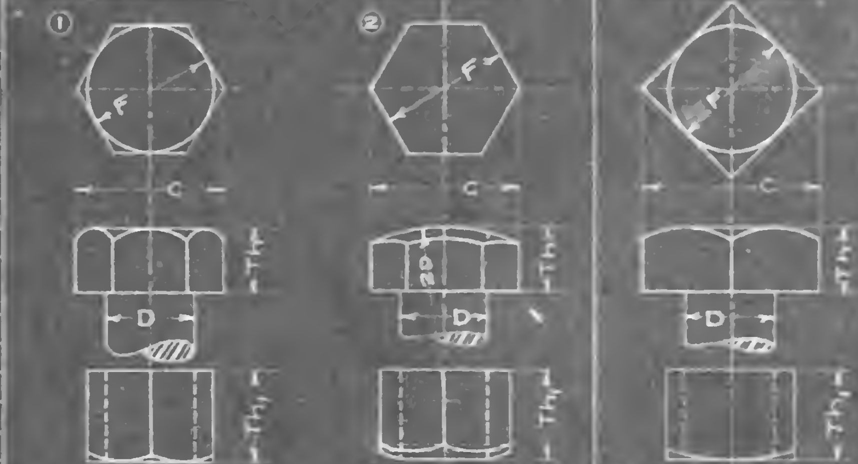
Nominal Size of Pipe	Outside Diam.	Thickness of Metal.	Threads per inch.
1/8"	0.405	.068	27
1/4	0.640	.088	18
3/8	0.675	.091	18
1/2	0.840	.109	14
3/4	1.050	.113	14
1	1.315	.134	11 1/2
1 1/4	1.660	.140	11 1/2
1 1/2	1.900	.145	11 1/2
2	2.375	.154	11 1/2

III.

U.S. STANDARD BOLTS AND NUTS

HEXAGONAL — Chamfered ① — Rounded ②

SQUARE — Chamfered



Hexagonal, Rough: F = 1½D + 1/8, C = F × 1.15, Th = ½F, Th₁ = D

Hexagonal, Finished: F = 1½D + 1/16, C = F × 1.15, Th = ½F, Th₁ = D − 1/16

IV.

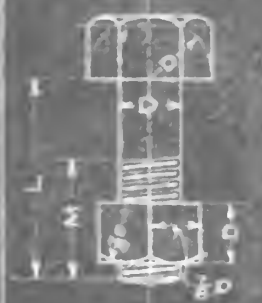
Square, Rough: F = 1½D + 1/8, C = F × 1.41, Th = ½F, Th₁ = D

Square, Finished: F = 1½D + 1/16, C = F × 1.41, Th = ½F, Th₁ = D − 1/16

V.

CONVENTIONAL METHOD

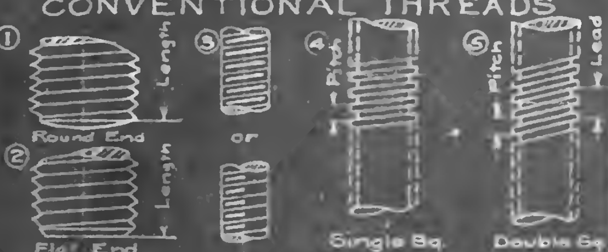
OFTEN USED IN DRAWING SMALL HEXAGONAL BOLTS



Necessary Dimensions: D, L, M

VI.

CONVENTIONAL THREADS



For Large "V" Threads — For Small "V" Threads

NOTE: Pitch usually defined as 8 threads per inch, 10 thr. p. in., etc.

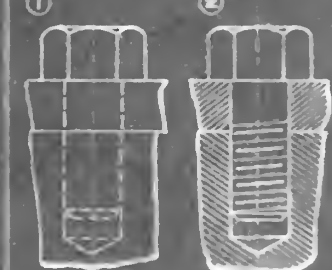
VII.

TAPPED HOLES

THREE METHODS

VIII.

BOLTS IN PLACE



IX.

STUD BOLT

X.

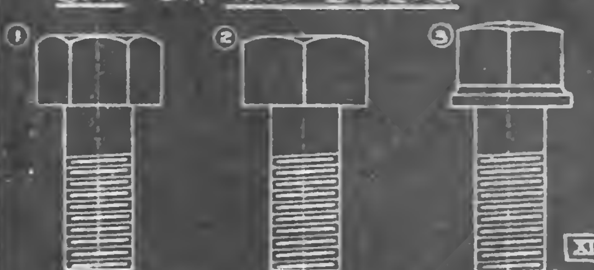
CHECK NUT

XI.

LAG SCREW

XII.

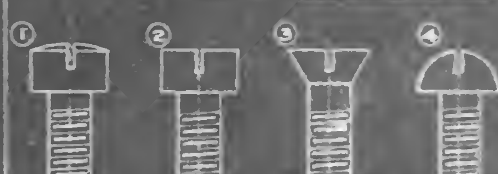
CAP OR TAP BOLTS



① Hexagonal Head — ② Square Head — ③ Collared

XIII.

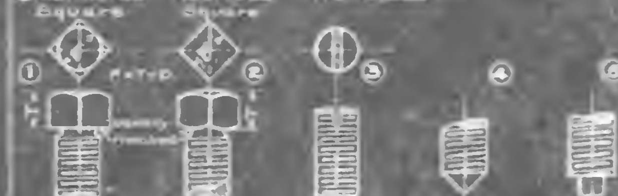
CAP OR MACHINE SCREWS



① Fillister Head — ② Round or Cheese Head — ③ Flat or Countersunk — ④ Button Head

XIV.

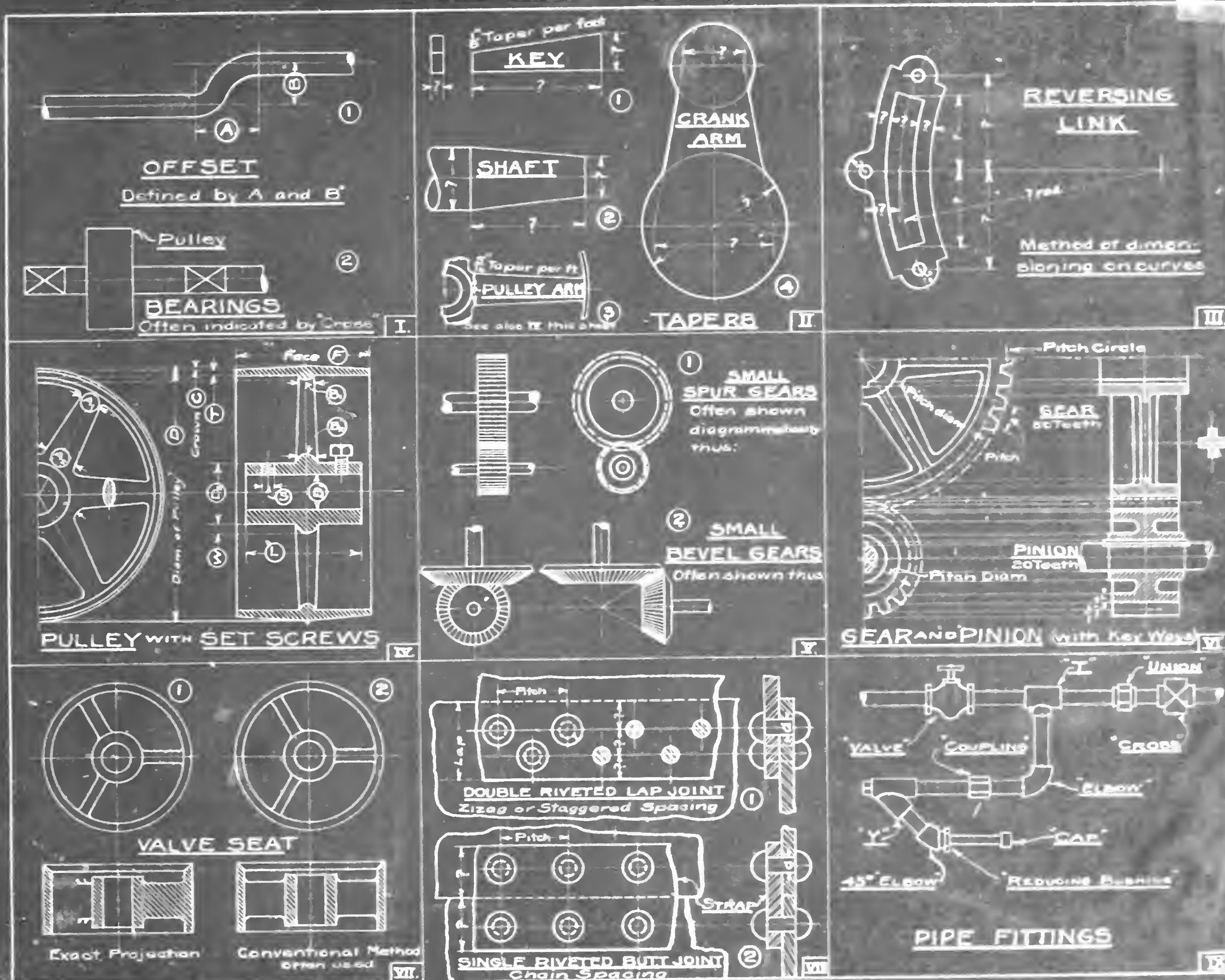
SET SCREWS



① Round Point — ② Cup Point — ③ Flat Point — ④ Cone Point — ⑤ Pivot Point

XV.

References — Reid, Elemen. Mach. Des. (Chap. I) — Bartlett, Mech. Draw. pp. 36-75 — Anthony Mach. Drawing Chap. I.



SOME CONVENTIONS IN DIMENSIONING AND DRAWING

Plate E

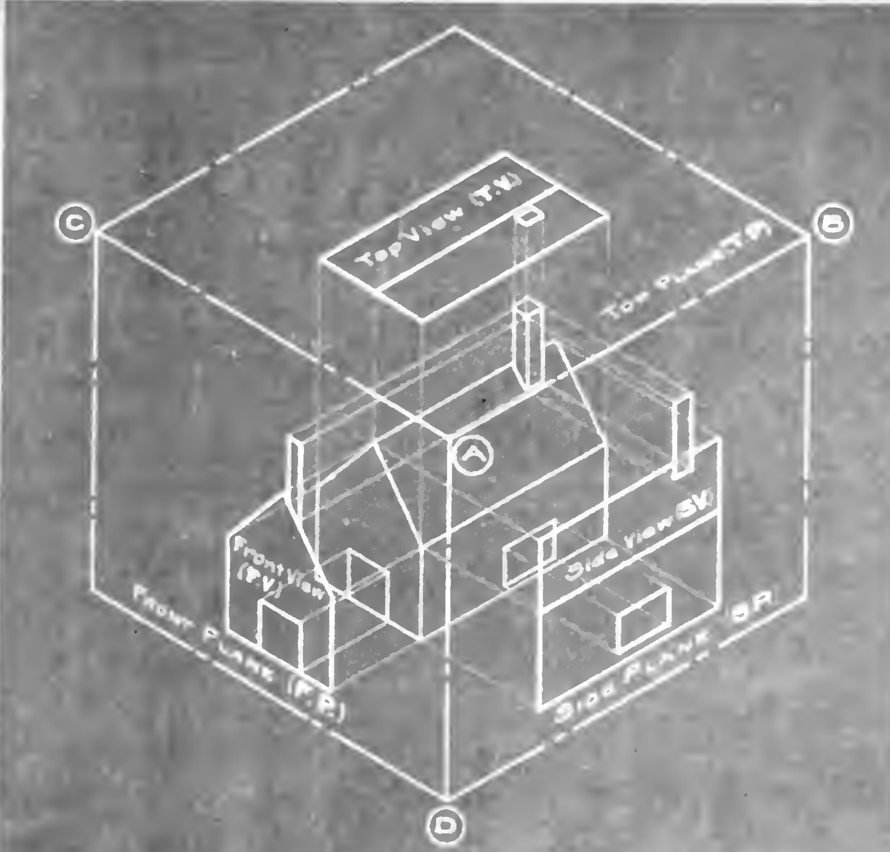


Fig. 1

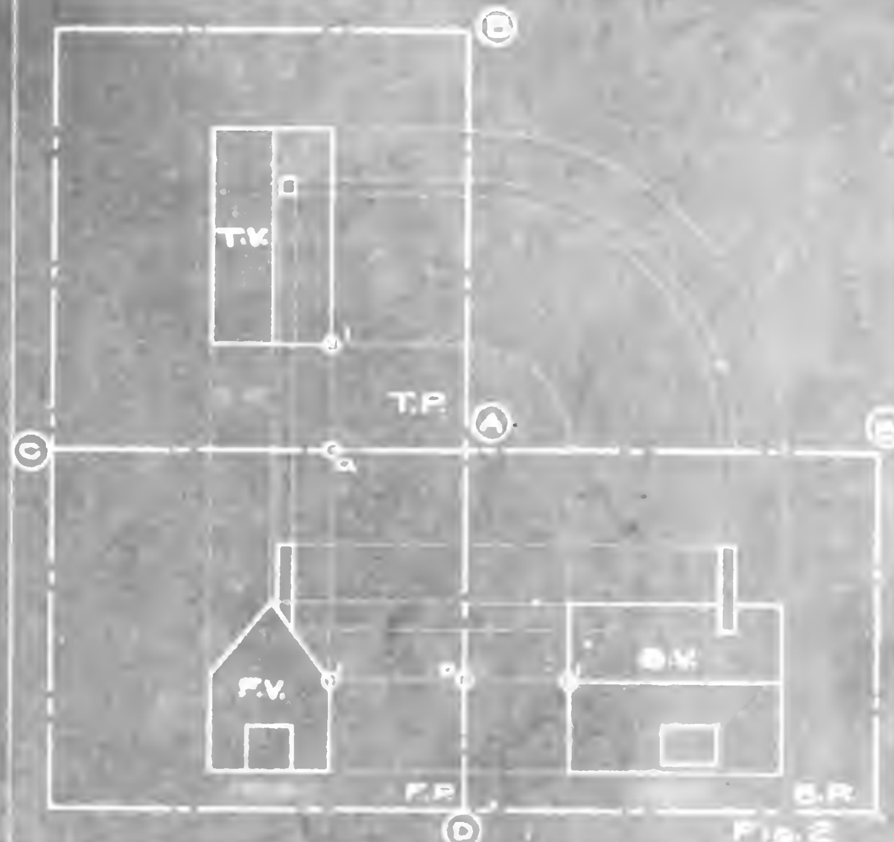


Fig. 2

1. Consider object surrounded by Three Planes, F.P., S.P. and T.P. as shown (Fig. 1).
   These planes are called "PLANES OF PROJECTION"

2. Let rays perpendicular to each plane respectively, pass from every point of object to these planes.

3. The intersection of these rays and their respective planes will trace Three Views, F.V., S.V. + T.V. as shown (Fig. 1).

4. These views are called the "PROJECTIONS" of the object

* Note (a) More accurately, the "ORTHOGRAPHIC PROJECTIONS" because the rays make Right Angles with their respective planes. ὀρθός = Right + γράφειν = to Draw.
(b) By additional planes a Bottom View, a Left Side View and a Rear View can be obtained.

5. Consider the Planes of Projection to be separated along AB. Turn T.P. on AC and S.P. on AD and spread all three planes out flat. The resulting location of the views will be as in Fig. 2.

6. Note that (a) T.V. is above F.V., and S.V. at side of F.V.§
   (b) Point 1 in T.V. is vertically over point 1 in F.V.
   (c) Point 1 is on same horizontal line in S.V. and F.V.
   (d) Distance [illegible] in S.V. = distance [illegible] in T.V.
   These 4 relations are true for all corresponding [illegible]

7. The above principles apply to the representation of all objects by the method of Orthographic Projection.

§ Note: F.V. often called Front Elevation.
S.V. " " Side Elevation.
T.V. " " Plan.

ORTHOGRAPHIC PROJECTION

Plate [illegible]